LITANI WATER QUALITY MANAGEMENT PROJECT

TECHNICAL SURVEY REPORT

JUNE 2005

LITANI BASIN MANAGEMENT ADVISORY SERVICES (BAMAS)

BUREAU FOR ASIA AND THE NEAR EAST

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

REPORT PREPARATION

This report was prepared by *Development Alternatives, Inc.* (DAI), 7250 Woodmont Avenue, Bethesda MD 20814 USA (under contract with the United States Agency for International Development, Contract Number LAG-I-00-99-00017-00, the Integrated Water and Coastal Resources Management (WATER IQC) Task Order No. 818) in collaboration with *Water and Environment Sustainable Solutions s.a.r.l.* (WESS) and *Khatib and Alami Consolidated Engineering Company s.a.l.*, Beirut, Lebanon.

EXECUTIVE SUMMARY

Following recommendations of the Rapid Review Task, which was completed in January 20, a *Winter Technical Survey* was conducted in February-May 2005, as part of Task 2 of the Litani BAMAS Project, to identify and profile point and non-point pollution sources, assess current status of the surface and groundwater quality and other environmental parameters, conduct interviews with stakeholders to assess health and environmental impacts of water pollution and gauge farmers attitudes and practices on water use, fertilization, and pesticide management. Consultation, via meetings and workshops, with various government institutions; industrialists and other private sector representatives; and members of civil society including local municipalities, NGOs, and farmers associations; has been organized since the start of the project. It led to the establishment of the project National Working Group and an overwhelming participation of stakeholders in discussing survey results and shaping recommendations related to water quality management/pollution remediation investment options.

This report presents a detailed description, analysis, and findings of this survey, which covers an environmental sampling and analysis campaign, and questionnaires related to 1) planned and proposed wastewater treatment plants (WWTPs) in the upper Litani basin, 2) potential health and environmental impacts associated with water pollution, and 3) potential impacts related to irrigation practices and agrochemical usage. The report also illustrates the project participatory process, identifies six recommended water quality/pollution remediation investment options, and outlines future project interventions.

Surface and ground water sampling campaign

Site reconnaissance visits conducted in February 2005 ascertained the presence of various point sources pollution along the Litani River and its tributaries, including domestic wastewater discharge, industrial effluent, and solid waste landfill/disposal sites. In all cases, it was observed that wastewater/industrial effluents were directly discharged into rivers without prior treatment.

The sampling program comprised of collection of water samples from the Litani River and its tributaries; groundwater samples throughout the basin; water samples from Canal 900; water, sediment, and fish samples from the Qaraoun Lake; and soil samples from irrigation areas adjacent to Canal 900. The collected samples were analyzed for a pre-defined set of bacteriological, physical, and chemical parameters and the results were compared with international and national standards for different water uses. Table I presents the number of collected samples and the corresponding type of analysis.

Table I. Type of analysis conducted on the various samples collected

Matrix	*No. of samples*	*Analysis type*	
		Type I- Full Analysis	*Type II- Partial Analysis*
River water Lake water Canal water Industrial wastewater Domestic wastewater	125 30 14 9 20	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD ▪ Lead ▪ Mercury ▪ Cadmium ▪ Chromium	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD
No. of samples		*56*	*142*
Groundwater	60	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Nickel ▪ Copper ▪ Zinc ▪ Lead ▪ Mercury ▪ Cadmium ▪ Chromium ▪ Organochlorines ▪ Organophosphorous	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates
No. of samples		*30*	*30*
Soil Lake sediments	20 10	▪ Ammonia ▪ Total nitrogen ▪ Total carbon ▪ Phosphates ▪ Lead ▪ Cadmium ▪ Chromium	
No. of samples		*30*	
Fish	9	▪ Lead ▪ Cadmium ▪ Chromium	
No. of samples		*9*	

The main results of the sampling campaign are as follows:

- Several chemical and biological indicators exhibited concentrations exceeding drinking, bathing, domestic, and irrigation water quality standards at the wet season when the dilution effect is highest. Evidently, the contamination levels will only get worse during the dry summer season.
- Field observations and water quality analysis indicate that the most significant sources of contamination to surface and groundwater are associated with the uncontrolled discharge of untreated wastewater along the Litani River and its tributaries highlighting the need for investing in wastewater treatment plants.

- The highest levels of contamination along the river fall within the mid-upper Litani basin where the largest communities are located and are discharging into the river.
- The quality of the water in Qaraoun Lake and in Canal 900 was found to be acceptable for irrigation under certain restrictions.
- The high levels of nitrates in groundwater samples ascertained the impact of current agricultural practices on groundwater quality and the importance of extension programs to insure proper application of fertilizers in the dry season.
- Soil, sediment and fish samples exhibited low to high levels of heavy metals. Additional analysis is needed to assess the implications of these levels.
- The wet season results are certainly not reflective of the worst case conditions in the basin. The planned dry season campaign will provide a more comprehensive understanding of the level of environmental stresses and hence will further assist in defining investment options to enhance environmental management towards the improvement of water quality in the basin.

Planned wastewater treatment plants

As recommended by the Rapid Review (RR), information related to existing and planned Wastewater Treatment Plants (WWTPs) in the Upper Litani Basin were updated based on the master plan approved by the Ministry of Energy and Water (MEW) and the Council for Development and Reconstruction (CDR), and an ongoing initiatives particularly the program funded by the United States Agency for International Development (USAID) for the study and design of WWTPs in the Upper Litani Basin under a contract with Camp, Dresser & McKee (CDM). It was concluded that whereas both plans (CDR-MEW and CDM) target wastewater management in villages geographically distributed throughout the Upper Litani Basin, a significant number of villages (46 percent) in which 13.3 percent of the population resides is still not served within their schemes.

Health Farmer and Agricultural Surveys

The field Health Survey examined waterborne illnesses associated with degraded water quality in the upper Litani Basin to assess the damage cost of water pollution in the basin for the year 2004. For this purpose, a questionnaire was developed and administered at hospitals and dispensaries in the upper Litani river basin including the districts of Baalbek, Zahle and West Bekaa covering a total of 46 medical facilities. The health survey revealed that recorded cases of 6,150 waterborne illnesses during the year 2004 are considered to be a minimum estimate. The majority of these cases was recorded near large communities and their distribution is consistent with the pattern of greater levels of pollution detected near these communities and which are predominantly associated with the discharge of untreated wastewater in the Litani River. The time and resource constraints did not allow the survey of private clinics and pharmacies to capture a more representative diarrhea and typhoid cases in the basin. Similarly, the survey did not capture children mortality related to water pollution.

The field Farmers Survey investigated the damage associated with algae proliferation along Canal 900 as a result of the development of eutrophic conditions associated with increased nitrogen and phosphorous levels that are directly linked to wastewater discharge and agricultural practices throughout the basin. This damage will translate into an incremental cost to farmers in terms of equipment damage and potential decrease in the retail value of their produce associated with the negative social perception regarding irrigation with polluted water from Canal 900. The farmers' survey revealed that the damage to equipment as a result of algae proliferation appears to be limited to drip irrigation systems and main filter intakes.

The Agricultural Survey gathered and analyzed information related to the impacts of on-farm practices on water quality management in the upper Litani River Basin and Lake Qaraoun. The questionnaire addressed several issues including land tenure, cultivation and farm management practices, and agrochemical use. The survey revealed that agrochemical usage and application rates are generally not appropriate. As such, an agricultural extension program is needed to alleviate the water pollution problem in the upper Litani basin originating from agricultural practices, while taking into consideration the production problems faced by the farmers to ensure farmer buy-in and cooperation.

Recommendations

Based on the results of the *Technical Survey,* the 2nd National working group meeting, and the 2nd project workshop, the upper Litani Basin stakeholders endorsed the following six water quality management/pollution remediation investment options:

- Coverage of gaps in domestic wastewater management;
- Strengthening capacities in operation and maintenance of WWTPs;
- Integrated efficient water use-fertigation/pesticide management- crop production agricultural extension programs;
- Long-term water (SW-GW) quality monitoring program;
- Strengthening capacities in Industrial Wastewater Management & Environmental Compliance: regulatory, incentive based, and voluntary compliances;
- Strengthening capacities in Solid Waste Management.

It was also recommended to consider the subsequent key support tools for the design and implementation of above options:

- Stakeholder participation including Public and private institutions, civil society (NGOs, other associations, gender);
- Public Awareness;
- Training and capacity building;
- Institutional strengthening;
- Legal support.

Future Project Interventions

The following activities are planned for the remaining project period:

- Work with NWG on identification of institutional responsibility for each of the above recommended six water quality management/pollution remediation options;
- formulate and cost of each option;
- Continue implementation of the algae program including training of LRA staff;

- Conduct Summer sampling survey;
- Complete DSS for prioritization of domestic wastewater management options;
- Complete groundwater modeling to identify groundwater vulnerability areas, essential for groundwater quality monitoring and management;
- Start preparation of Action plan;
- Convene three NWG meetings and two workshops

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LIST OF ABBREVIATIONS

AUB	American University of Beirut
AREC	The American University of Beirut's Agricultural, Research and Education Center
BAMAS	Basin Management Advisory Services
CDM	Camp Dresser and Mckee
CDR	Council for Development and Reconstruction
Daly	Disability Adjusted Life Year
ECL	Environmental Core Laboratory at AUB
EERC	Environmental Engineering Research Center at AUB
GPS	Global Positioning System
DAI	Development Alternatives Inc.
MEW	Ministry of Energy and Water
MoE	Ministry of Environment
MoPH	Ministry of Public Health
NPS	Non-point Source
RR	Rapid Review
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WESS	Water and Environment Sustainable Solutions s.a.r.l.
WHO	World Health Organization
WWTP	Wastewater treatment plant

1. INTRODUCTION

The upper Litani River basin and Lake Qaraoun suffer from potential water pollution problems which are due to uncontrolled solid and liquid domestic and industrial waste disposal practices, in addition to agrochemical usage and lack of sustainable wastewater management. This situation may cause negative water use impacts on public health, environment, and socio-economic development. Hence, there is a need for proper management of the quality of the surface and ground water resources to eliminate or minimize these impacts and pave the way for environmentally sustainable and socio-economically viable use of these vital resources. The main objective of the Litani Water Quality Management Basin Advisory Services (BAMAS) Project is to identify and assess management and investment options and scenarios for water quality improvement and remediation of potential pollution for the upper Litani River basin and Lake Qaraoun (Figure 1) and develop an environmental management plan for their implementation.

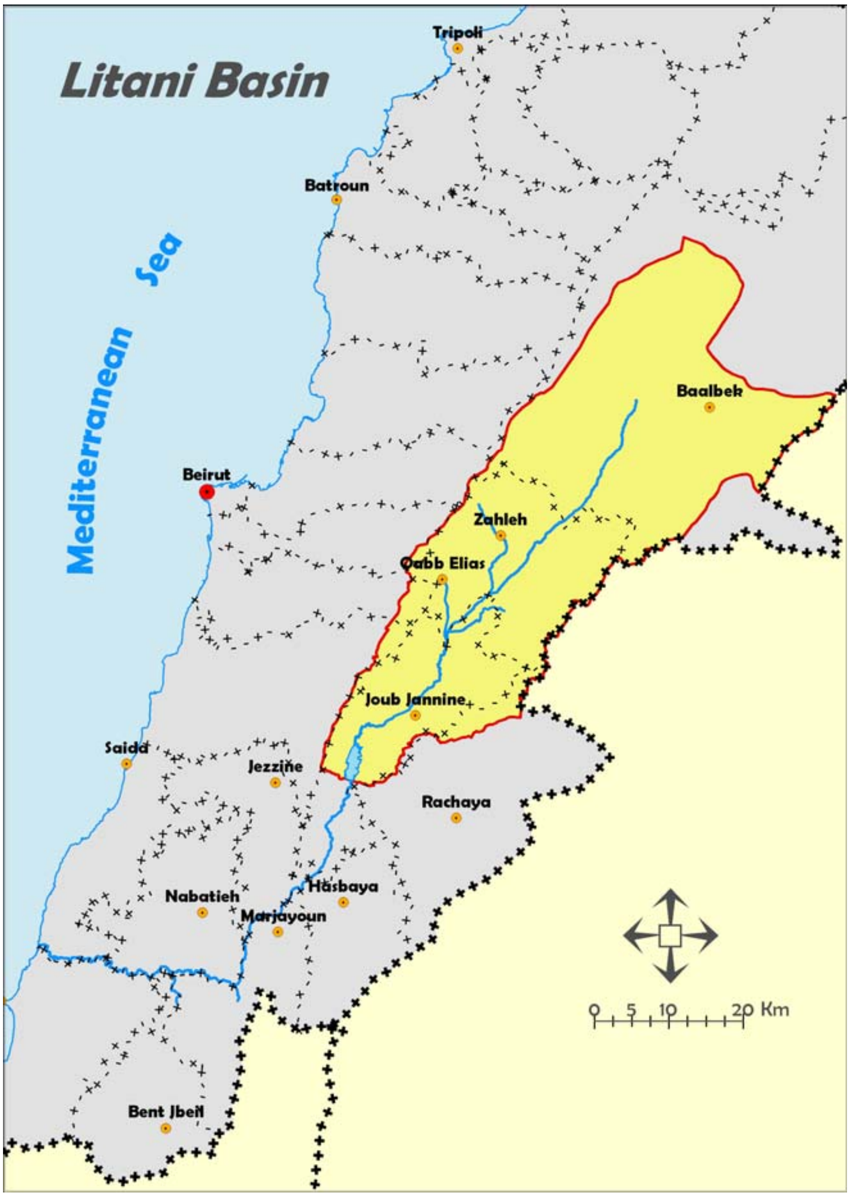


Figure 1. Overview map of the upper Litani River basin

The Project focuses on five tasks which will be implemented through collaborative planning interventions, policy discussions, frequent consultations, workshops, field surveys, socio-economic analyses, exploration of lessons learned from best practices, institutional strengthening and capacity building, and development of an analytical Decision Support System. The tasks are as follows:

- ***Rapid Review*** of background information related to water quality, identification and interview of key stakeholders, and development of specific recommendations for future project interventions;
- ***Technical Survey*** to collect and analyze additional information based on the rapid review recommendations in order to assist in the identification of potential investment and management options related to water pollution remedial and water quality management;
- ***Identification of Potential Options for Water Quality Management and Water Pollution Remediation Investment Options*** based on the findings of the technical survey;
- ***Development of a Water Quality Management Decision Support System***, to help in the selection of water quality management options and scenarios in the basin and formulation of the environmental management plan; and
- ***Capacity Building*** of stakeholder staff through active participation and hands-on experience in various project activities including: data collection, analysis, legal and institutional strengthening, and modeling.

The rapid review (RR) task, which was completed in January 20, presented the current state of knowledge of water quality and environmental stresses in the Upper Litani and Lake Qaraoun basin illustrating the lack of groundwater quality data and the need to fill in gaps in surface water quality data. General consensus was reached by a wide representation of stakeholders on the endorsement of the RR recommendations which include supplementing information related to technical, health, and socio-economic aspects of water quality management during the technical survey task. Accordingly, the *Technical Survey* task includes two surface and ground water quality sampling campaigns (one in the winter and one in the summer), administration of questionnaires about potential health and environmental impacts associated with water pollution as well as potential impacts related to irrigation practices and agrochemical usage, and a series of other technical and institutional/legal activities recommended in the RR.

This report presents a description and results of the completed activities in the *Technical Survey* task, including the field reconnaissance, environmental sampling and analysis campaign (surface and ground water, sediments, soil, and fish), a survey of planned and proposed wastewater treatment plants (WWTPs) in the upper Litani basin, and the health, farmers, and agricultural surveys. The methods for legal and institutional analysis of investment options are defined and collaborative-participatory planning efforts to date are documented.

2. FIELD RECONNAISSANCE

A site reconnaissance was first carried out in an attempt to characterize the upper Litani basin before initiating the sampling program. Site visits were conducted during February 2005 to (a) acquire a better understanding of the Litani river-tributaries network, particularly water sources, flow paths, and confluences; (b) ascertain the land use pattern in the basin, particularly areas adjacent to the river and Canal 900; (c) document major sources of environmental stress, including wastewater discharge (domestic or industrial), agricultural runoff, and solid waste landfills or dumpsites; and (d) locate groundwater wells throughout the basin, and gather information about their existing conditions. Field observations coupled with photographic documentation were systematically recorded on a field reconnaissance log book, a sample of which is presented in Appendix A, with corresponding location description, coordinates using a Global Positioning System (GPS), and other relevant information. The objective of the combined information is to define pertinent sampling locations.

2.1 Field observations

Site visits coupled with existing topographic maps as well as meetings and discussions with local municipalities, farmers, and residents formed the basis for defining the drainage system of the upper Litani basin and its tributaries, verifying the land use of areas adjacent to the river, and locating groundwater wells and major sources of environmental stress. The river network, along with its tributaries, and existing land use pattern in the basin are depicted in Figure 2. The Hydrology, hydrogeology and geology of the upper Litani basin, and details on Canal 900 are described in Appendix B.

As depicted in the land use map of the upper Litani basin (Figure 2), the Litani river passes for the most in areas characterized by its rural agricultural nature, with the exception of sections in Tamnnine el Tahta, Rayak, Bar Elias, El Marj, Mansoura, and Ghazzeh areas, where some residential areas or industrial activities dominate. On the other hand, large cities such as Zahle and Chtoura, and most of the industrial activities are located in the major subasins.

Field observations and documentation ascertained the presence of various point sources of pollution along the Litani river and its tributaries (Figure 3) (refer to Appendix C for a list of observed sources of pollution). Sources vary between domestic wastewater discharge, industrial effluent, and solid waste landfill/disposal sites (Figure 4). In all cases, it was observed that wastewater/industrial effluents were directly discharged into rivers without prior treatment, except at two instances in Joub Jannine and Loceh-Ghazeh where preliminary sedimentation for domestic wastewater is practiced (Figure 5). Moreover, the field surveys revealed that at many locations where an industrial facility is not adjacent to the main Litani water course, effluents flow considerable distances until they reach a receiving water body that ultimately discharges into the Litani river. This was true for the SICOMO cardboard factory in Qabb Elias area[1], Sugar beet factory in Majdel Aanjar area[2]; Master chips factory in Ferzol area[3]; and Liban Lait facility and farm in Haouch Enabi area[4] where cow manure flows off the premises of the facility through an earthen canal that discharges into the Litani river at an appreciable distance downstream (Figure 6).

[1] Facility, 1WR043; discharge at Jair river, 1WR042
[2] Facility, 1WF031; discharge at Ghzayel river, 1WR026
[3] Facility, 1WF182; discharge at Litani river, 1WR171
[4] Facility; 1WR146; discharge at Litani river, 1WR145

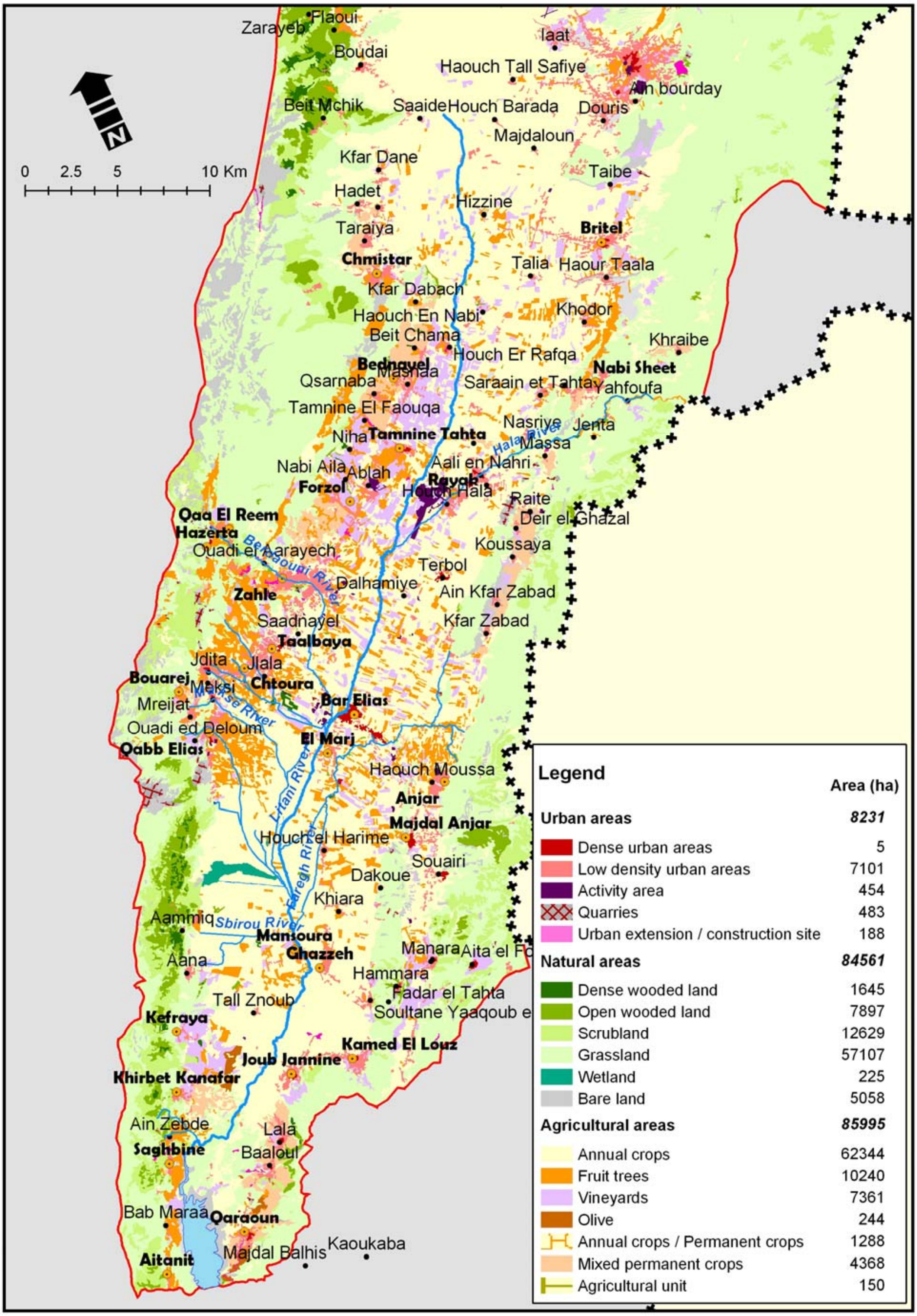


Figure 2. Litani river and its tributaries with existing land use in the upper basin

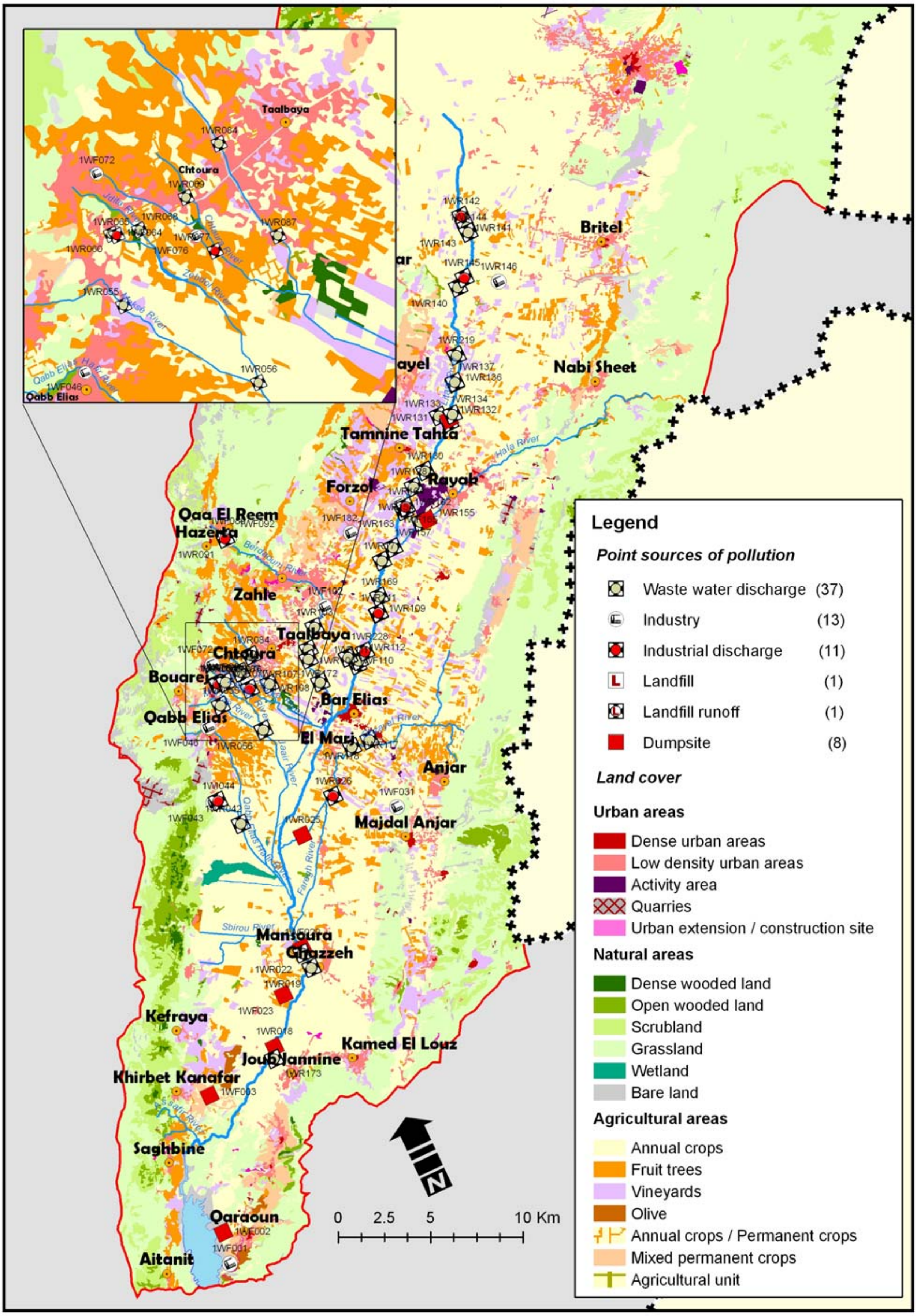


Figure 3. Point and non-point sources of pollution documented during reconnaissance

Domestic wastewater
(Bednayel, Litani river)

Industrial discharge (Tanmiya facility)
(Ablah, Litani river)

Landfill (Zahle, Litani river)

Dumpsite (Qsarnaba, Litani river)

Figure 4. Examples/types of point sources of pollution documented during the field surveys

(a) Preliminary sedimentation

(b) Cleaning access port

(c) Overflow discharge

Figure 5. Preliminary wastewater sedimentation in Joub Jannine

(a) Effluent from within facility premises

(b) Flows through earthen channel

(c) Discharges into Litani river

Figure 6. Liban Lait manure discharge into the Litani river through an earthen canal

Reconnaissance of Canal 900 revealed that no algae accumulation was observed throughout the Canal length at the time of field surveys, however, the transparency of the Canal water drastically changed between its start point in Qaraoun area and towards the dead end in Kamed El Laouz (Figure 7). Moreover, it was observed that the Canal section behind each of the three installed flow control gates (Figure 8) acts like a reservoir. The Canal was drained at the end of the winter season for cleaning and maintenance prior to the irrigation season. Sediment and residual algae were evident (Figure 9).

As for the surveyed groundwater wells, their majority are used for drinking and/or irrigation purposes, while some are used to supply water for industrial activities. The field surveys revealed the poor conditions of some wells in terms of improper casing and corresponding exposure to potential hazards, while others were adequately equipped and maintained.

Near start point

Mid way Towards the dead end

Figure 7. Change of water transparency along Canal 900 length

Figure 8. Flow control gate at Canal 900

Figure 9. Sediment and algae residue at the bottom of the Canal during cleanup

2.2 Rationale for sample selection

The rapid review (USAID, 2005) defined a sampling program for the upper Litani basin to complement or fill in the gaps of previous and on-going monitoring activities in the basin. The program comprises the collection of water samples from the Litani river and its tributaries, groundwater samples throughout the basin, water samples from Canal 900, water, sediment, and fish samples from the Qaraoun lake, and soil samples from irrigation areas adjacent to Canal 900. The rationale for selecting the sample locations is outlined below within the context of the timeframe allocated to the field surveys and resource constraints.

Surface water

Water sampling along the upper sections of the Litani river and its tributaries focused on assessing the potential impacts resulting from effluent discharges along the river. Wherever feasible, effluent samples were collected at the point of discharge, and at distances ranging between 100 and 500 meters downstream or upstream of a discharge point depending on accessibility. Similarly, samples were collected at confluence points from tributaries and the main river course at locations upstream and downstream of the confluence point. On the other hand, for stretches of the river where no effluent discharges were observed, samples were collected at various distances in an attempt to characterize the river water quality along these stretches. Around 26 domestic and industrial effluent samples were collected from discharge points and 128 river water samples were collected from 95 locations along the river. Overall, 142 samples underwent partial analysis (physico-chemical and microbiological) and 56 samples underwent full analysis (physico-chemical, microbiological, and heavy metals) as detailed in Section 3.1. The sampled locations and corresponding type of analysis along the Litani river and its tributaries are presented in Figure 10. Appendix D presents a brief description of the sampled locations.

Groundwater

The groundwater sampling campaign aimed at characterizing the prevailing groundwater quality within the upper Litani basin. The 60 sampled wells were selected based on the sources of potential pollution identified during the reconnaissance field surveys, the land use map of the basin area, accessibility, and adequate spatial representation. In this context, typical locations targeted areas with extensive agricultural activities, areas near solid waste dumpsites or landfills, and remote areas with minimal human activities representing background conditions. The geographic distribution of sampled groundwater wells and the type of analysis the samples underwent is presented in Figure 11 together with the type of analysis whereby 30 wells underwent partial analysis (physico-chemical and microbiological) and the other 30 underwent full analysis (physico-chemical, microbiological, heavy metals, pesticides). Most sampled wells are in the Beqaa Valley, thus tapping into the Neogene-Quaternary aquifer at a depth of 70 to 100 m below ground surface, with the exception of the wells to the south-east of the axis Ghazzeh – Joubb Jannine, 4 wells are tapping in the Eocene, 11 in the Cenomanian and 3 in Khirbet Qanafar and Kefraya in the Jurassic[1]. Appendix E presents a brief description of the sampled wells.

[1] The Eocene and Cenomanian aquifers are both karstified. Where these formations are exposed, they offer preferential flow path leading directly to the aquifer which reduces the residence time in the vadoze zone. On the other hand, the Neogene-Quaternary aquifer is composed of alluvia with lower hydraulic conductivity providing higher resistance for water movement and longer residence time in the vadoze zone, hence allowing physical, biological, and chemical processes to take place leading to natural degradation of the pollutants, mainly pesticides which are degraded by biological processes, and any eventual heavy metals adsorbed by soil layers.

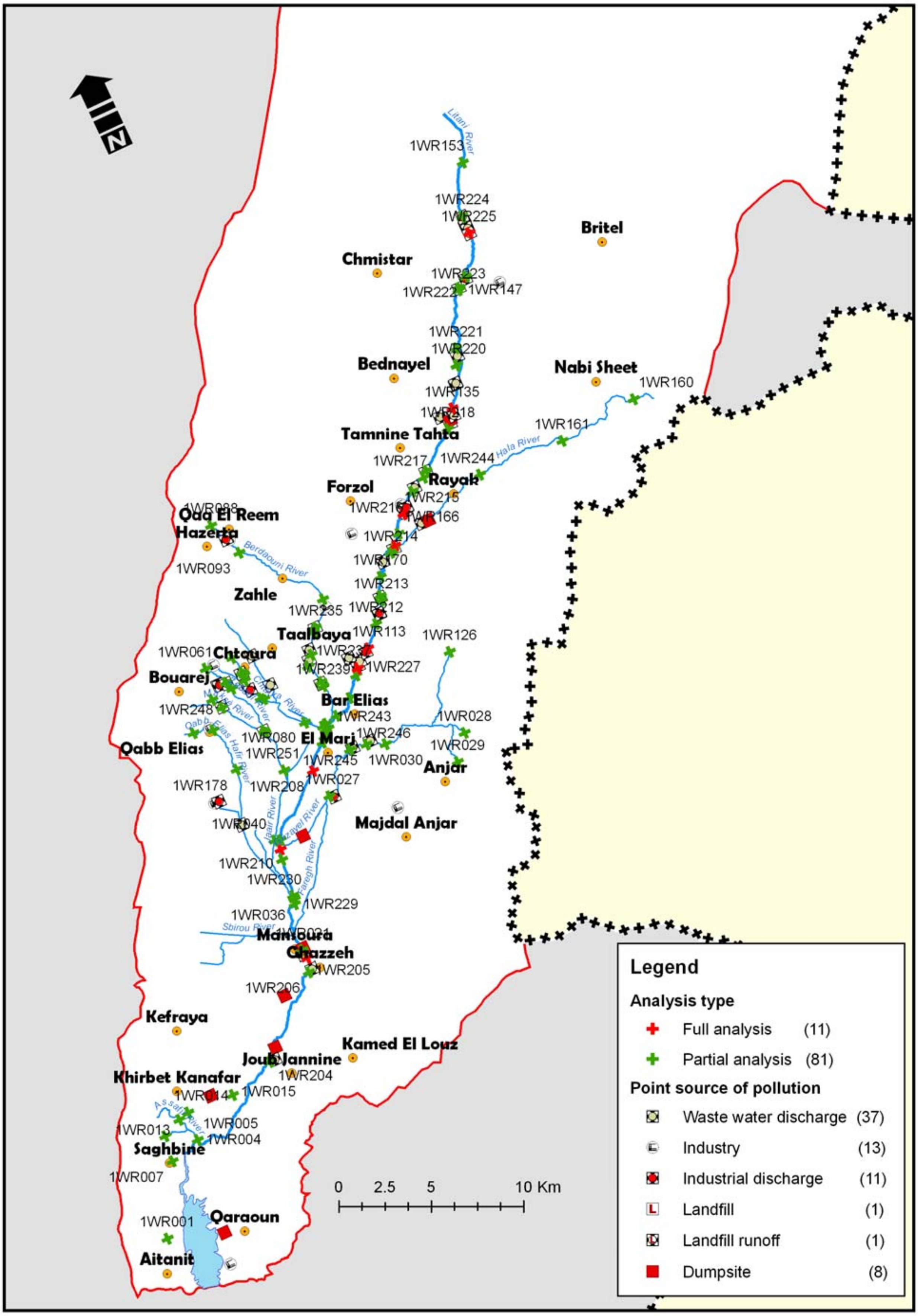


Figure 10. Location of water samples collected along the Litani river and its tributaries with corresponding type of analysis

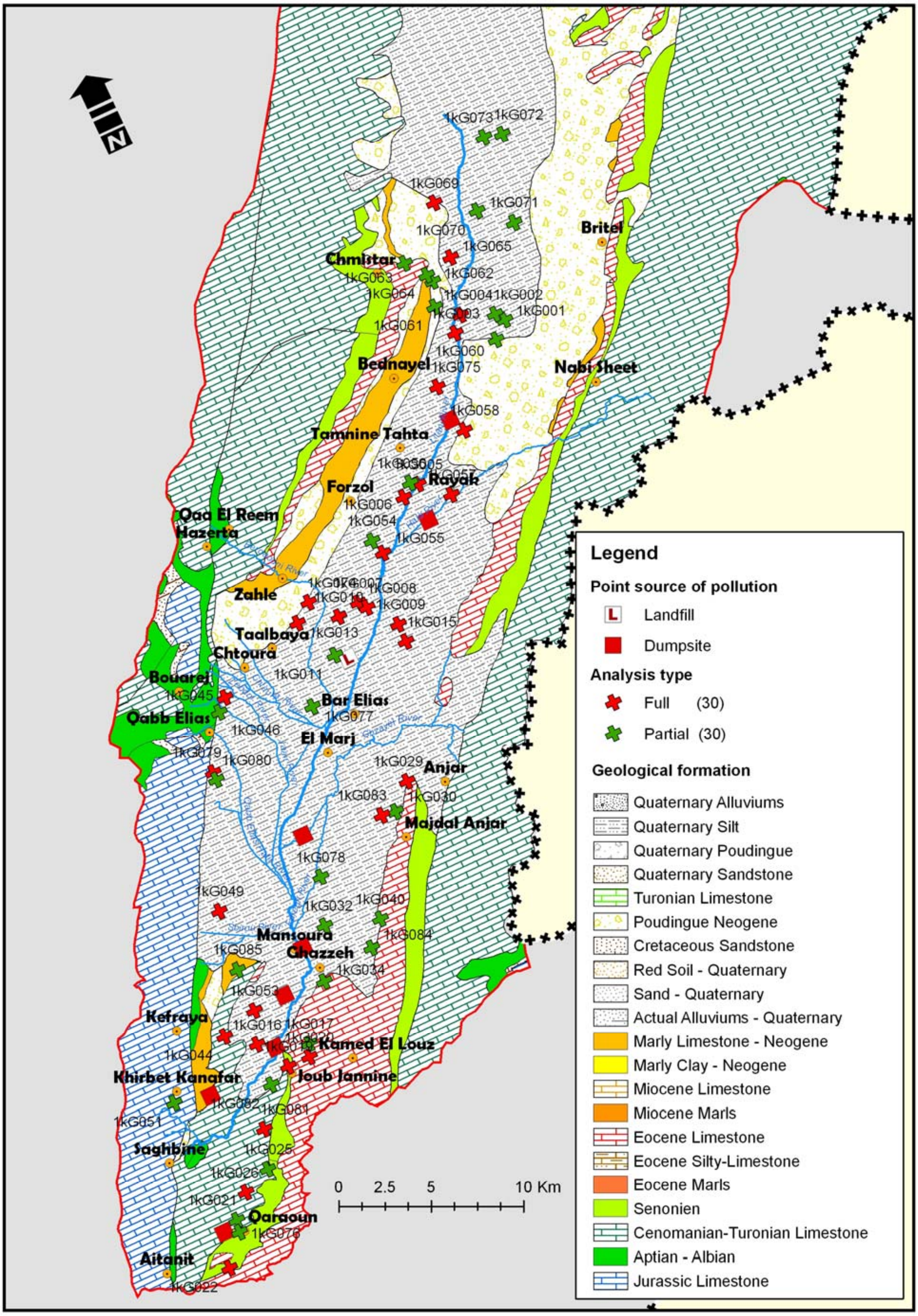


Figure 11. Location of sampled groundwater wells with corresponding analysis type

Lake water, sediment and fish

The sampling locations were selected to represent the whole water body in the lake. In this context, 30 samples were taken from 20 locations over the lake area as depicted in Figure 12. The water column at locations near the dam with greater depths was sampled at two depths (10 samples at 1/3 and 10 samples at 2/3 from the top); while at shallower locations 9 samples at mid depth were collected. The samples taken at 1/3 of the depth underwent partial analysis (physico-chemical and microbiological), while the others underwent full analysis (physico-chemical, microbiological, and heavy metals). Nine fish samples were collected from the lake using a net deployed by a local fisherman.

Canal 900

The samples were selected to represent the water quality along the Canal. Accordingly, 14 samples were collected from the three sections of the Canal behind the flow control gates and from the last stretch between the dead end at Kamed El Laouz and the last flow control gate in Joub Jannine. The locations of water samples along the Canal are presented in Figure 13. All Canal 900 samples underwent partial analysis (physico-chemical and microbiological).

Soil

Soil sampling in the upper sections of the Litani basin and in the agricultural lands along Canal 900 aimed at assessing the potential impacts on soil quality as a result of using the Litani water for irrigation. Accordingly, 5 soil samples were collected from each of the three agricultural zones irrigated from Canal 900 (Scheme 1-Qaraoun, Scheme 2-Lala, and Scheme 3-Joub Jannine-Kamed El Laouz), and 5 more samples were collected from the agricultural area near the diversion point from the Yammouneh irrigation canal (Scheme 4), which could be considered as background samples. The locations of collected soil samples are depicted in Figure 14. Appendix F presents a brief description of the sampled locations.

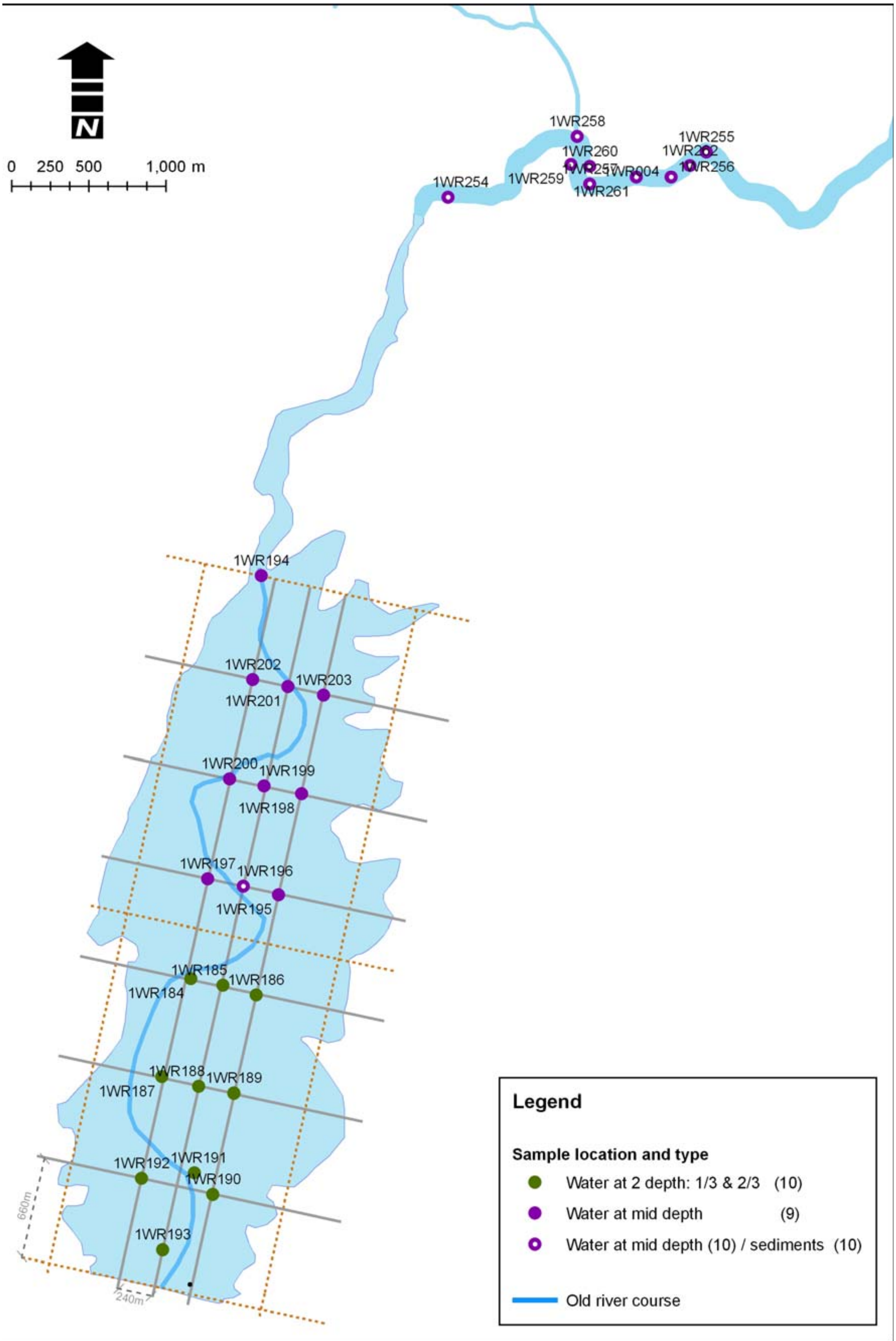


Figure 12. Location of water and sediment samples collected from the Qaraoun lake

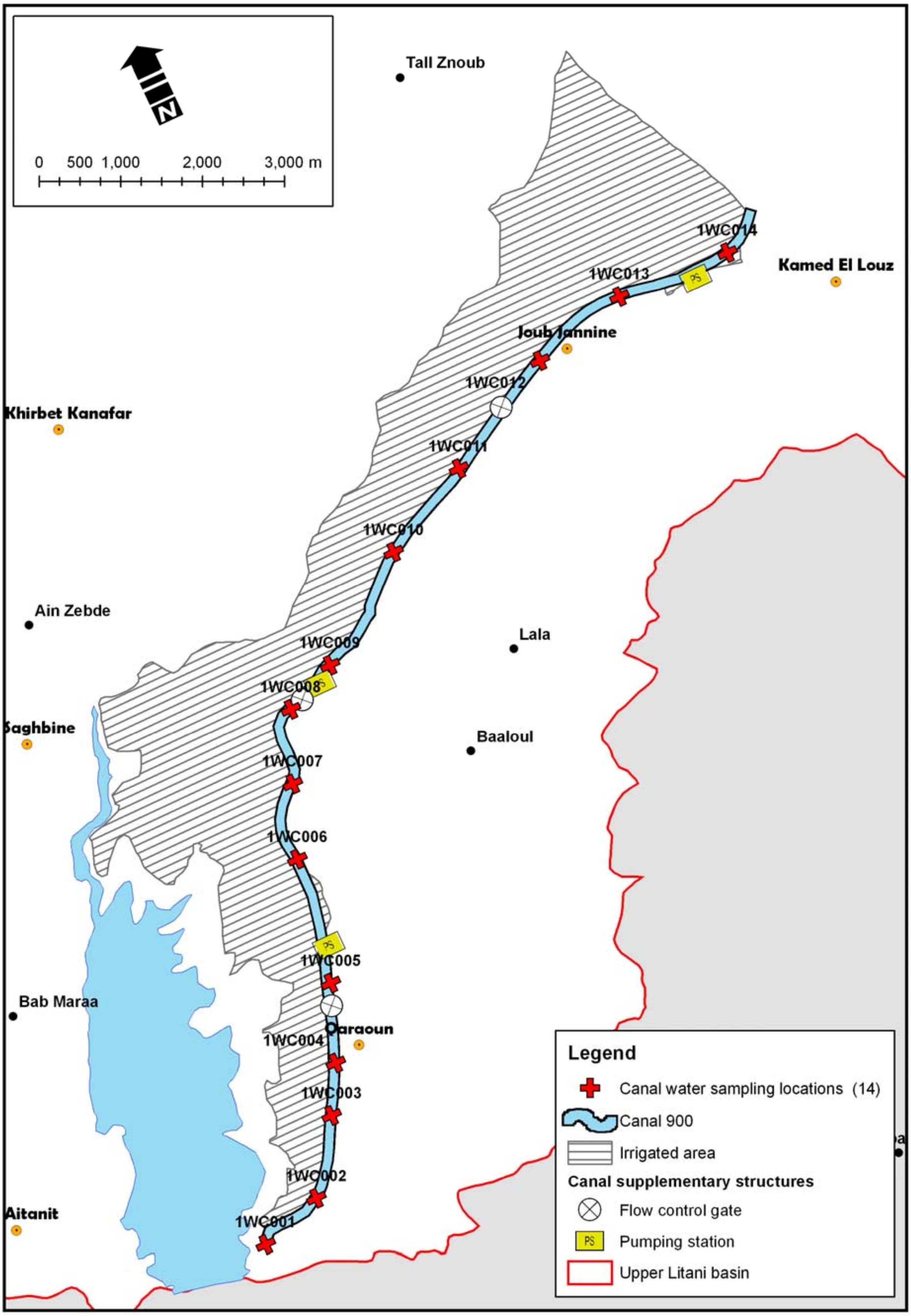


Figure 13. Location of water samples collected along Canal 900

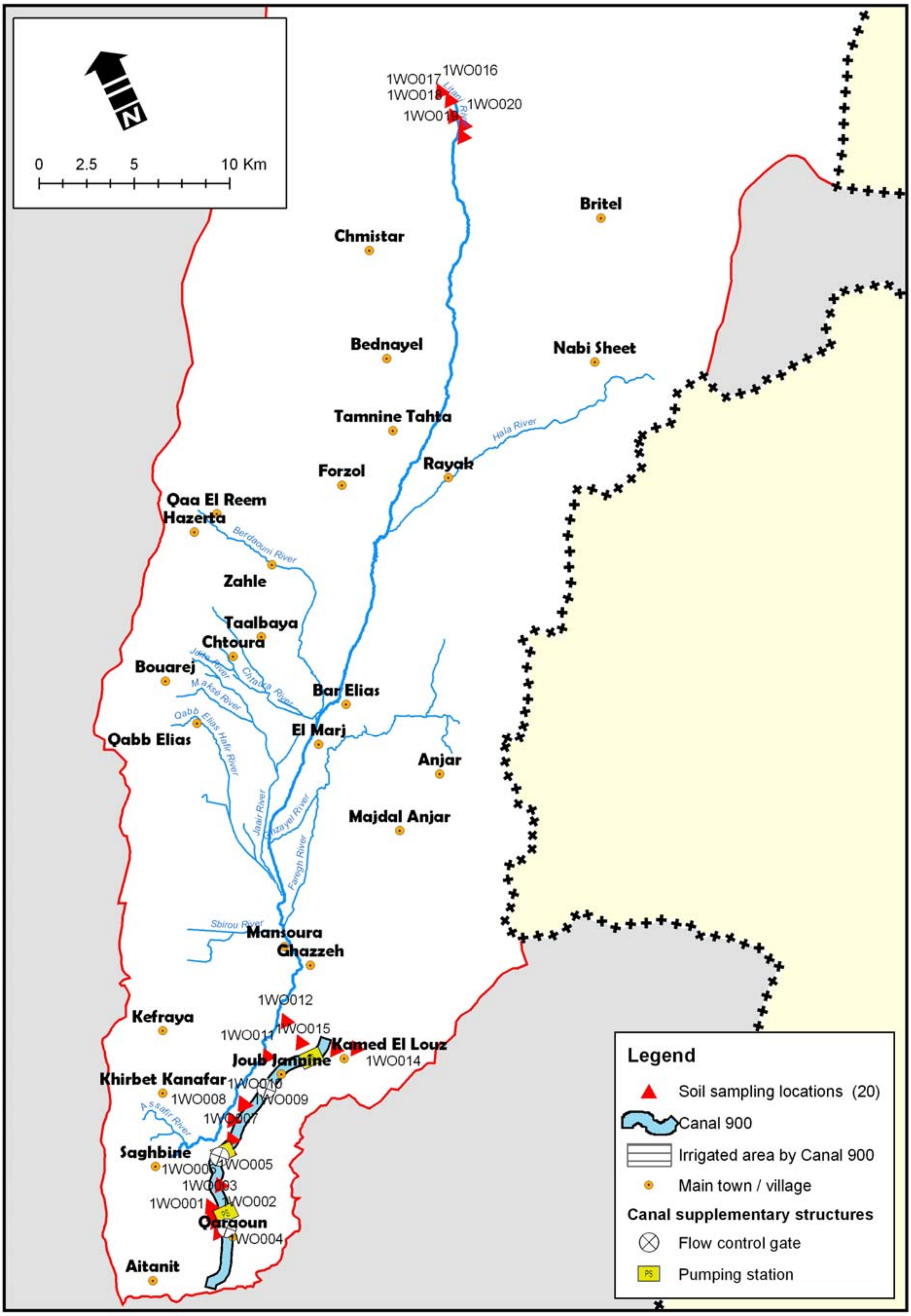


Figure 14. Soil sampling locations

A summary of the number of samples collected during the sampling program with corresponding selection rationale is presented in Table 1.

Table 1. Summary of samples collected with corresponding locations

Type	*No. of samples collected*	*General location*
Surface water	154	❑ Upstream and downstream of confluence and discharge points ❑ At distances along river stretches
Ground water	60	❑ Near potential sources of pollution (i.e. solid waste dumpsites/ landfills) ❑ In areas with intensive agricultural activities ❑ Remote areas with minimal human activities ❑ Spatially distributed in the upper basin area
Canal 900	14	❑ The three Canal sections behind each flow control gate ❑ The last section between the dead end and last flow control gate
Qaraoun lake	30	❑ At mid depth in shallow zones ❑ At 1/3 and 2/3 depth in deeper zones ❑ Spatial distribution over the lake area
Soil	20	❑ The three irrigated zones of Canal 900 ❑ Background samples from Saaide area near diversion from Yammouneh agricultural canal
Sediment	9	❑ The mouth of Qaraoun Lake ❑ Deep zones in Qaraoun Lake
Fish	9	❑ From the Qaraoun Lake

3. WATER QUALITY ASSESSMENT

3.1 Sample collection and analysis

Surface water (river and canal) samples were collected directly through bottle immersion at shallow depths. Groundwater samples were collected from a well, after allowing the water to flow for about 10 to 15 minutes, to ensure proper flushing. Samples for pesticides analysis were collected in amber sterile glass bottles. Samples for bacteriological and chemical analysis were collected in sterile glass and plastic bottles, respectively, and those for heavy metals analysis were collected in sterile plastic bottles preserved with acid (70 % Nitric acid). In all cases, sample collection, transport, holding and handling, as well as subsequent analysis were conducted in accordance to the "Standard Methods for the Examination of Water and Wastewater" as approved by the American Public Health Association, Water Environment Federation, and American Water Works Association. The adopted guidelines for sample collection are presented in Appendix G. Sediment samples from the Qaraoun lake were collected using an ekman grab bed sampler, while water samples were collected using a vertical deep water sampler. Soil samples were collected using a soil auger from a depth of 30 cm below surface. Several samples were extracted from the land plot to form a composite sample.

The collected samples (surface water – river, lake, and Canal 900 –, groundwater, soil, sediment, and fish) were analyzed for a pre-defined set of bacteriological, physical, and chemical parameters at the laboratories of the American University of Beirut (AUB). Table 2 presents the type of analysis conducted on the various samples. Analysis for heavy metals and pesticides were conducted at the Environmental Core Laboratory (ECL). The remaining analyses were conducted at the Environmental Engineering Research Center (EERC) to ensure timely sample analysis within a tight timeframe. Delivered samples to either laboratories were recorded on a daily log sheet (Appendix A) which serves as a chain of custody record. Moreover, onsite measurements of water pH, temperature, and dissolved oxygen (DO) were conducted using a portable pH/temperature meter (Cole Parmer, model no. 59002-00) and a portable microprocessor dissolved oxygen meter (Hanna Instruments, model no. HI9143). The environmental significance of analyzed parameters, and the analytical methodologies and reference methods are presented in Table 3.

Table 2. Type of analysis conducted on the various samples collected

Matrix	*Analysis type*	
	Type I- Full Analysis	*Type II- Partial Analysis*
River water Lake water Canal water Industrial wastewater Domestic wastewater	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD ▪ Lead ▪ Mercury ▪ Cadmium ▪ Chromium	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD
No. of samples	*56*	*142*
Groundwater	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Nickel ▪ Copper ▪ Zinc ▪ Lead ▪ Mercury ▪ Cadmium ▪ Chromium ▪ Organochlorines ▪ Organophosphorous	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates
No. of samples	*30*	*30*
Soil Lake sediments	▪ Ammonia ▪ Total nitrogen ▪ Total carbon ▪ Phosphates ▪ Lead ▪ Cadmium ▪ Chromium	
No. of samples	*30*	
Fish	▪ Lead ▪ Cadmium ▪ Chromium	
No. of samples	*9*	

Table 3. Analytical techniques and reference methods

Parameter	*Significance*	*Test type*	*Method reference*
pH	Indication of stress on aquatic life	Electrometry	SM 4500-H^+B
Dissolved oxygen	Indication of pollution by organic matter	Electrometry	SM 4500-OE
Conductivity/TDS	Indication of the presence of mineral salts	Electrometry	SM 2510B
Nitrate	Indication of fertilizer seepage	Colorimetry	SM 4500 $NO3^-$B
Phosphate	Indication of fertilizer seepage	Colorimetry	SM 4500-PE
Sulfate	Indication of industrial pollution	Colorimetry	SM 4500-SO4
Heavy metals	Indication of industrial pollution	Gas chromatography	EPA 200.8
BOD	Indication of domestic or industrial wastewater contamination	Membrane electrometry	SM 5210B
COD	Indication of domestic or industrial wastewater contamination	Closed reflux /coloremetry	SM 5220D
Ammonia	Indication of domestic or industrial wastewater contamination	Colormetry	HACH ® method 8155
Total coliform	Indication of the presence of disease-causing microorganisms	Membrane filtration	SM 9222B
Fecal coliform	Verification of wastewater contamination and the indication of the presence of disease-causing organisms	Membrane filtration	SM 9222D
Pesticides (Organo-phosphates & Organochlorines)	Indication of agricultural pollution	Gas chromatography	EPA 507 & 608

3.2 Results and discussion

Water samples from the Litani river and its tributaries, lake Qaraoun, Canal 900, and groundwater wells were analyzed for the indicators outlined above and the results were compared with international and national standards for different uses (Table 4). The complete laboratory analysis results for water (surface and ground), sediment, soil, and fish samples are presented in Appendix H.

Table 4. Summary of International and National water quality guidelines

Parameters	*Drinking water standard*			*Reclaimed wastewater for irrigation*								*USEPA (1992)*	
	MoE-Lebanon		*USEPA*	*MoE proposed guidelines (2005)*									
	GV[1] (20°C)	*GV[1] (25°C)*	*GV/MAL[2]*	*Class 1A[7]*		*Class 1B[7]*		*Class 2[7]*		*Class 3[7]*		*Long term*	*Short term*
				Avg	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*		
pH (pH units)	6.5-8.5	6.5-8.5	6.5-8.5	-		-		-		-		-	-
Temperature (°C)	12	NA[3]	NA	-		-		-		-		-	-
Total dissolved solids (mg/L)	400[4]	500[5]	500[5]	-		-		-		-		-	-
Dissolved oxygen (mg/L O_2)	NA	NA	NA	-		-		-		-		-	-
Ammonia (mg/l)	0.05 (as NH_4^+)	NA	NA	-		-		-		-		-	-
Phosphates (mg/L)	0.4 (as P_2O_5)	NA	NA	-		-		-		-		-	-
Nitrate (mg/L)	25	10 (as N)	10 (as N)	-		-		-		-		-	-
Sulfate (mg/L)	25	250	250	-		-		-		-		-	-
Biochemical oxygen demand (mg/L)	NA	NA	NA	10	15	25	40	30	45	30	45	-	-
Chemical oxygen demand (mg/L)	NA	NA	NA	-		-				-		-	-
Fecal coliforms (CFU[6]/100, ml)	0/100	0/100	0/100	5	23	100	200	200	400	1,000	2,000	-	-
Total coliforms (CFU[6]100, ml)	0/100	0/100	0/100	-		-		-		-		-	-
Heavy metals	-	-	-	-		-		-		-		-	-
Zinc (mg/l)	-	-	-	-		-		-		-		2	10
Copper (mg/l)	-	-	-	-		-		-		-		0.2	5
Cadmium (mg/l)	-	-	-	-		-		-		-		0.01	2
Chromium (mg/l)	-	-	-	-		-		-		-		0.1	1
Lead (mg/l)	-	-	-	-		-		-		-		5	10

[1] GV: Guideline value
[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency
[3] NA: Not applicable
[4] reference temperature at 20°C
[5] reference temperature at 25°C
[6] CFU: colony forming unit
[7] Avg= 30 day average, Max= Maximum, see description of classes

Class of Reclaimed Wastewater	**Spray Irrigation**	**Flood Irrigation and Surface Drip Irrigation**
Class 1A	• No access control • No setback to dwelling unit or occupied establishment	• No access control
Class 1B	• No access control; irrigate at times when public exposure is unlikely • 50 meter set-back from dwelling unit or occupied establishment	• No access control; irrigate at times when public exposure is unlikely
Class2	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate • 50 meter set-back from dwelling unit or occupied establishment	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate
Class 3	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate • 250 meter set-back from dwelling unit or occupied establishment • Low pressure/low trajectory irrigation system only	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate • 50 meter set-back to dwelling unit or occupied establishment

3.2.1 Surface Water

More than 90 percent of water samples collected along the Litani River and its tributaries exhibited high levels of Total and Fecal Coliforms exceeding the MoE guidelines for domestic use. Relatively low and acceptable levels were detected only at spring sources before encountering wastewater discharging into the river. Fecal and Total Coliform levels were mostly concentrated in the range of 25,000-50,000 CFU/100 ml, corresponding to untreated domestic wastewater discharge into the river (Figure 15 and Figure 16). Similarly, ammonia levels, which are also correlated with domestic wastewater discharge, exceeded acceptable standards in 54 percent of the samples (Figure 18). High BOD levels were also detected along several stretches of the river (downstream of Al Marj area), which was expected given the high volumes of domestic wastewater discharged without prior treatment. Depending on the location of the discharge points, the BOD levels decreased along some stretches of the river (Figure 17), to below the threshold level of 3 mg/L, possibly due to the dilution effect of the various tributaries that join the main Litani in this area. Naturally, the highest levels of contamination along the river fall within the mid-upper Litani basin where the largest communities are located and are discharging into the river.

While sulfate levels were acceptable all along the river, nitrate and phosphate levels exceeded recommended standards in 17 and 28 percent of the samples, respectively (Figure 18). These results are consistent with the fact that during the winter season, agricultural activities are relatively limited and therefore, the input of nitrates and phosphates from the application of agrochemicals is minimal, and of course the winter dilution factor contributes to further decreasing the concentrations in the river. Furthermore, similar to BOD levels, high nitrate and phosphate levels were mostly detected upstream of El Marj area prior to the high dilution effect from the various tributaries.

When compared with reclaimed wastewater guidelines for irrigation as proposed by the Lebanese Ministry of Environment, 79 to 90 percent of the samples exhibited Fecal Coliform levels exceeding the threshold set for Class 3 and Class1A, respectively and 1 to 9 percent of the samples had a BOD level exceeding the threshold for the same classes (Figure 19 and Figure 20). Hence, direct irrigation from the river water is clearly not advisable.

Heavy metals were reported to be below the detection limits due probably to the dilution effect. These levels are likely to increase during the dry summer season when water flows are minimal.

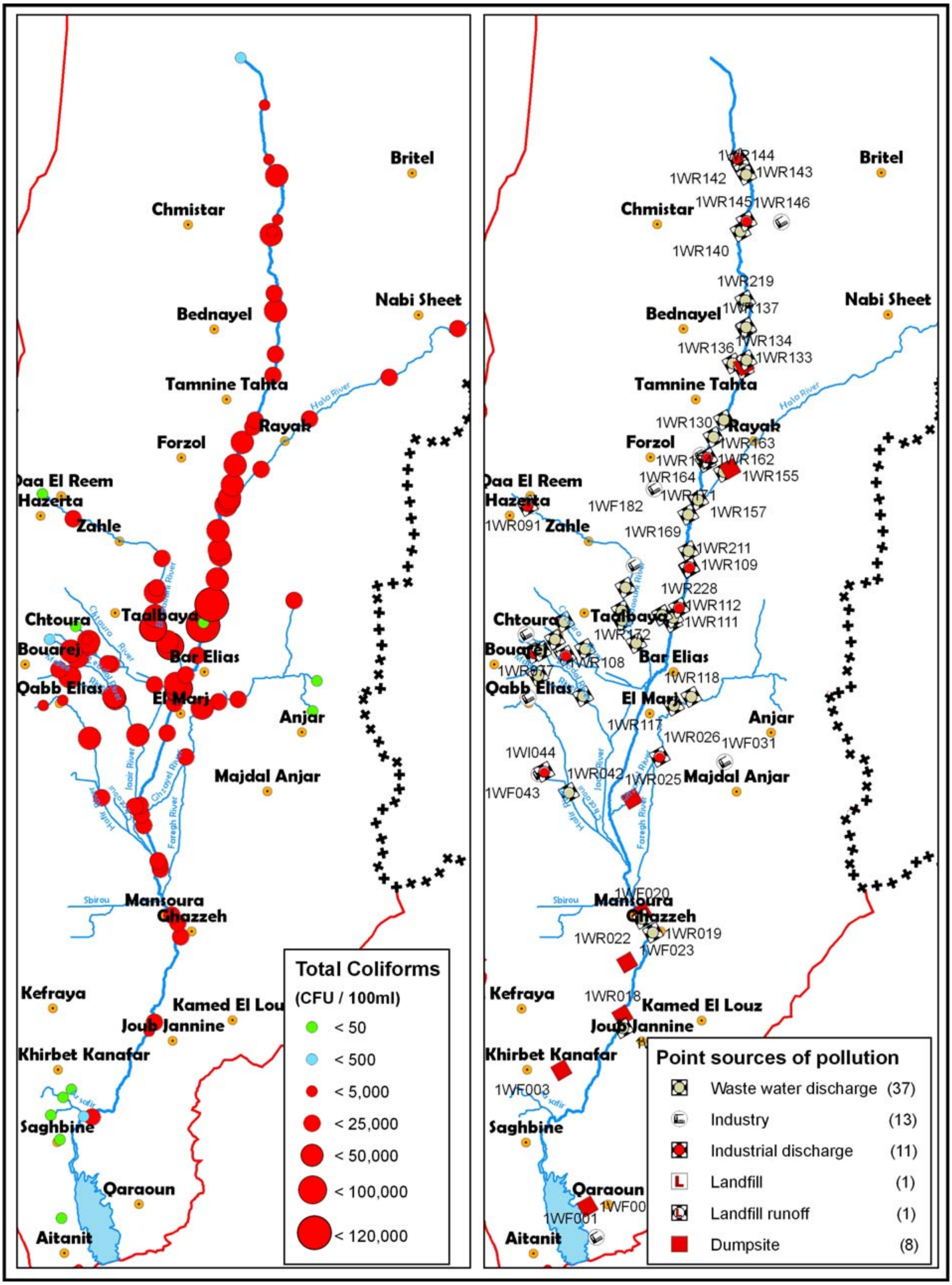


Figure 15. Analysis results for water samples along the Litani River and its tributaries (Total Coliform)

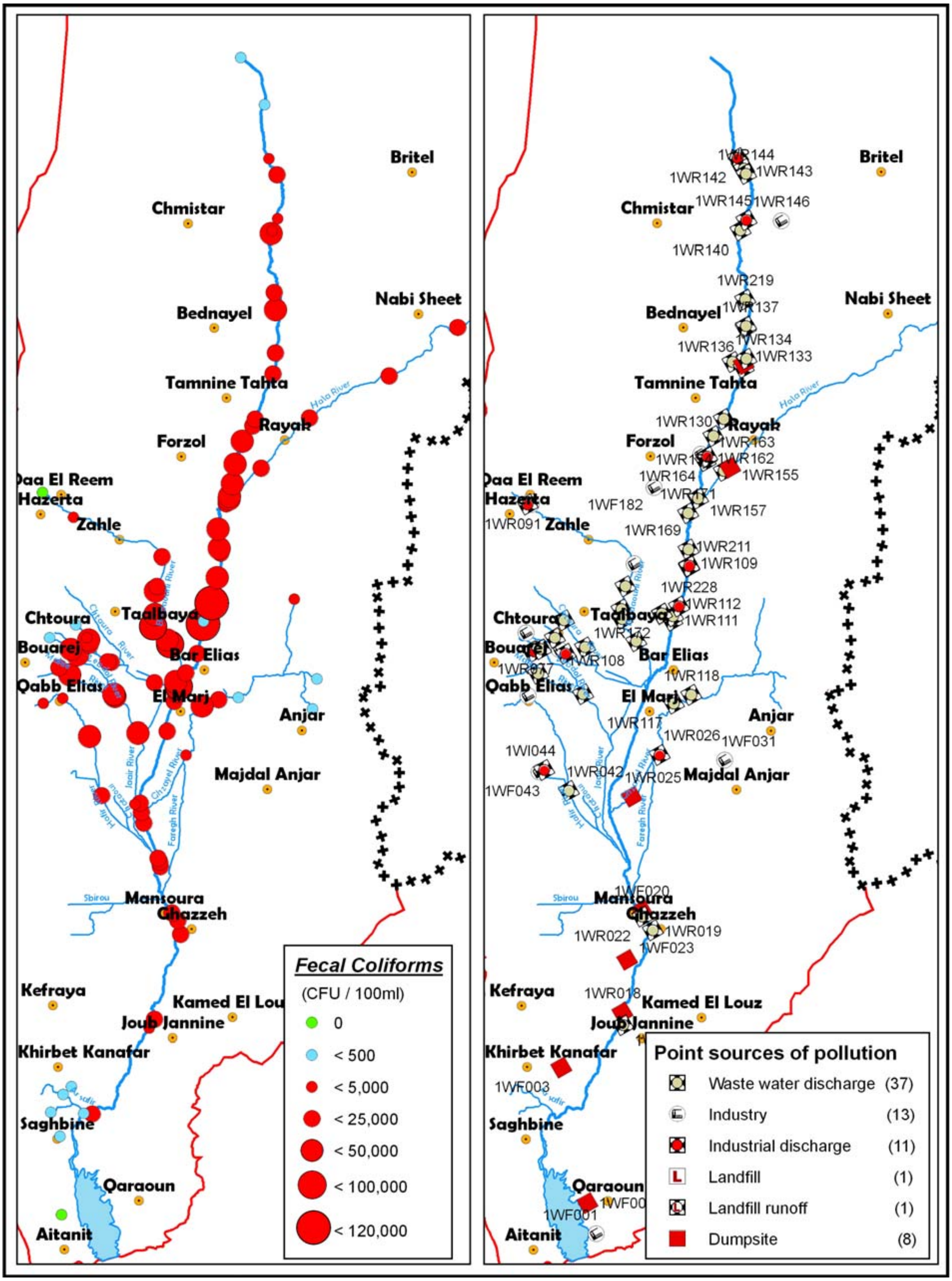


Figure 16. Analysis results for water samples collected along Litani river and its tributaries (Fecal coliform)

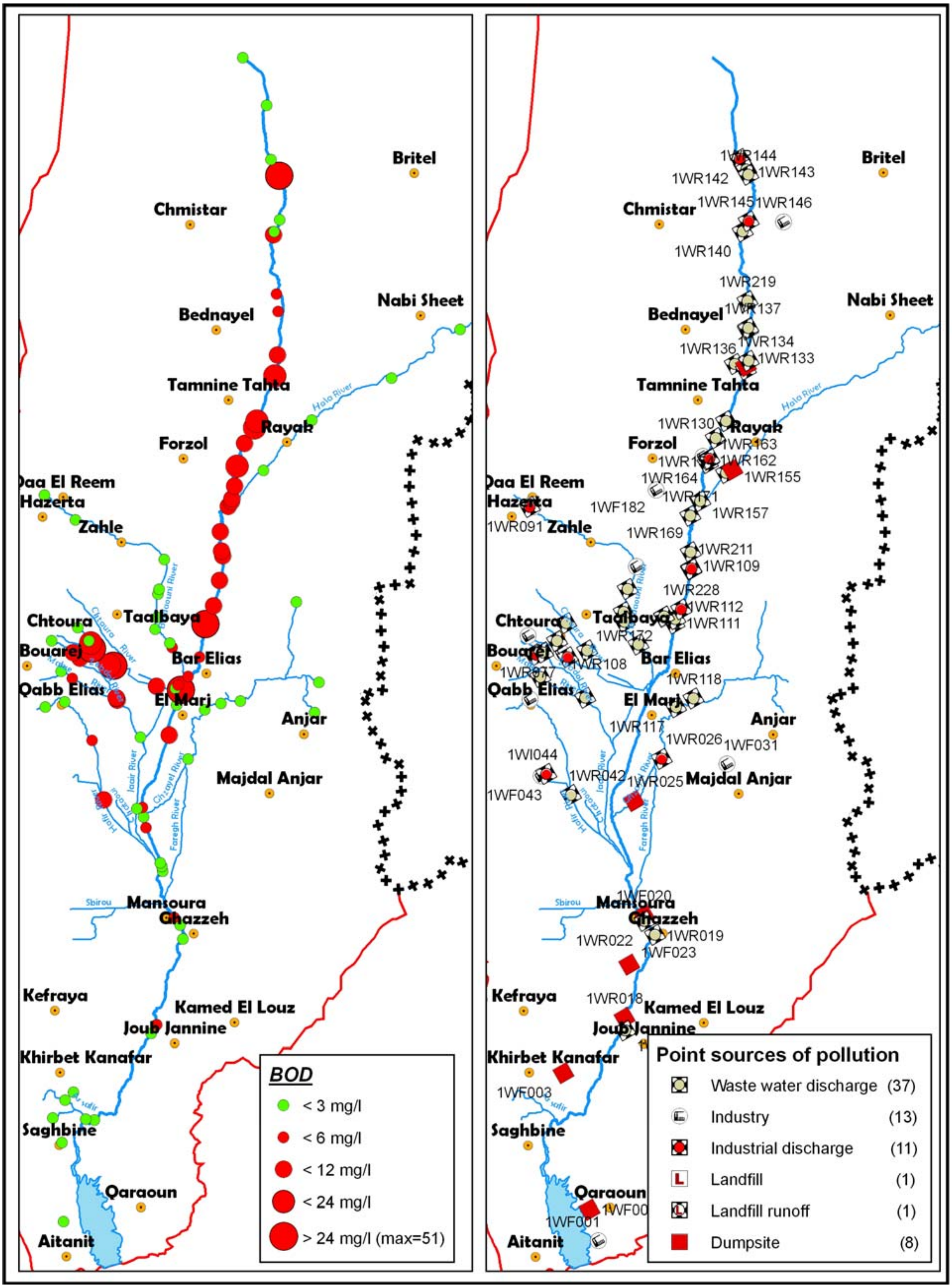


Figure 17. Analysis results for water samples along the Litani River and its tributaries (BOD)

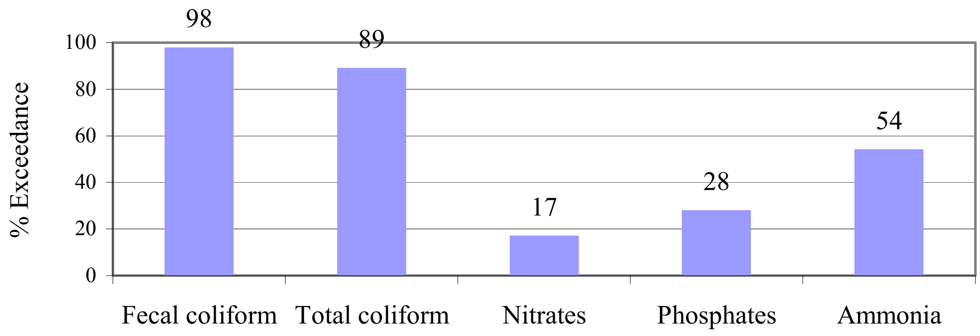


Figure 18. Percentage of samples along the Litani River and tributaries exceeding MoE water quality standards for domestic use

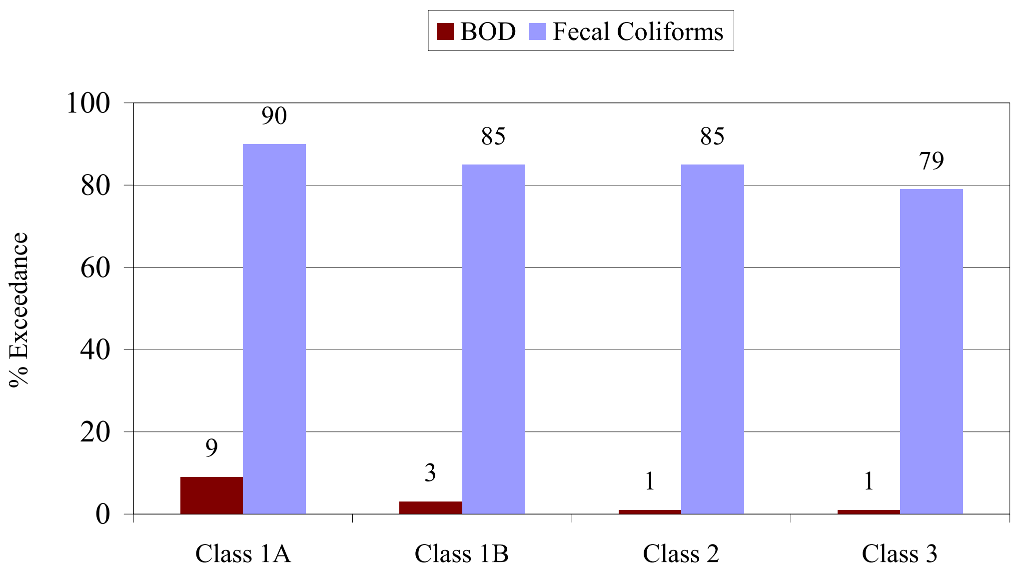


Figure 19. Percentage of samples along the Litani River and tributaries exceeding proposed Lebanese MoE water quality guidelines for irrigation

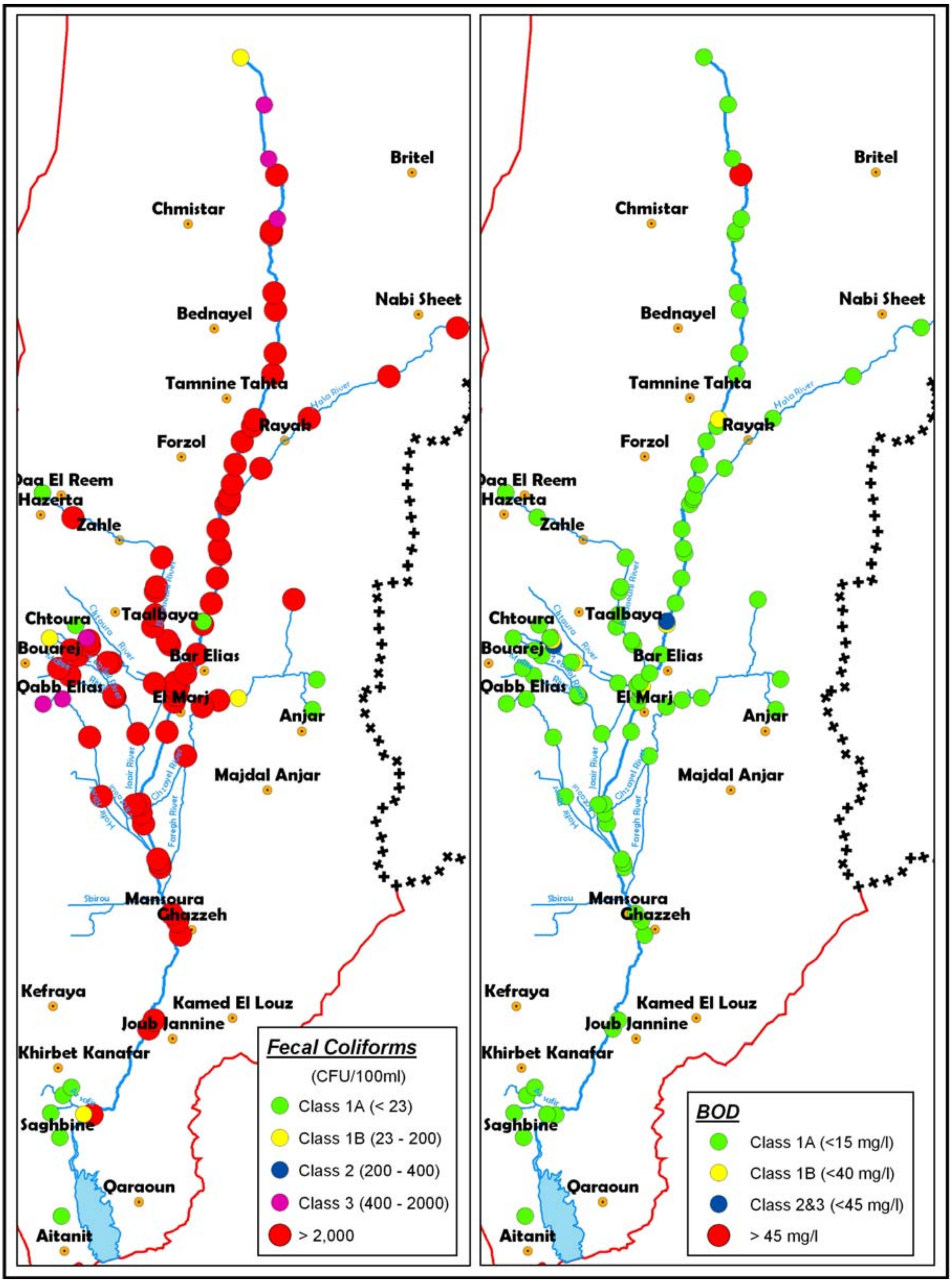


Figure 20. Analysis results of water samples along the Litani river and its tributaries (BOD and Fecal Coliform) based on the classes of the proposed Lebanese MoE water quality guidelines for irrigation

3.2.2 Qaraoun Lake

Water flowing in the Litani river drains towards the Qaraoun Lake. As such, the quality of the water in the Lake reflects to a great extent the quality of the River water, with some variations imposed by Lake dynamics (dilution, stratification, currents, sedimentation). As such, Lake water samples exhibited total and fecal coliform and ammonia levels exceeding drinking water standards in 60, 100, and 100 percent of the samples, respectively (Figure 21). High nitrate levels were also detected whereby 73 percent of the samples exceeded the standards. Phosphate and sulfate levels which were acceptable in the river water were also acceptable in the Lake water samples.

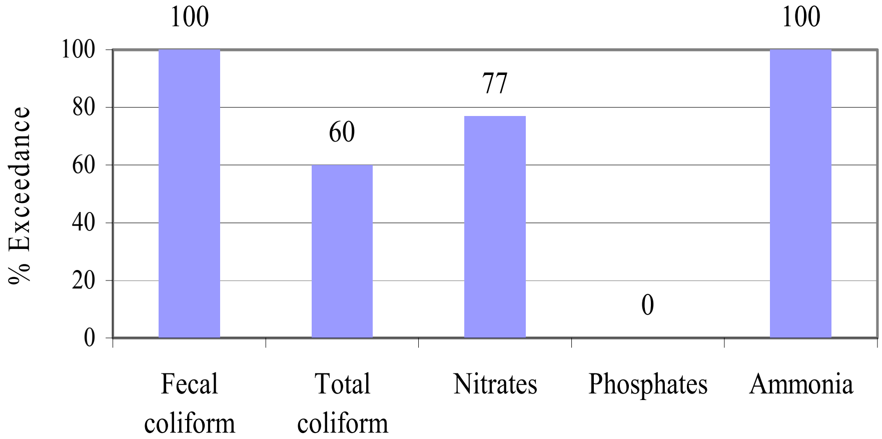


Figure 21. Percentage of samples from the Qaraoun Lake exceeding Lebanese MoE water quality standards for domestic use

When compared with reclaimed wastewater guidelines for irrigation as proposed by the Lebanese Ministry of Environment, all water samples from Qaraoun Lake were within the BOD and FC thresholds for classes 1B, 2, and 3, while only 30 percent of the samples exhibited fecal coliform levels within the threshold set for Class1A, irrigation with no access control (Figure 22 and Figure 23).

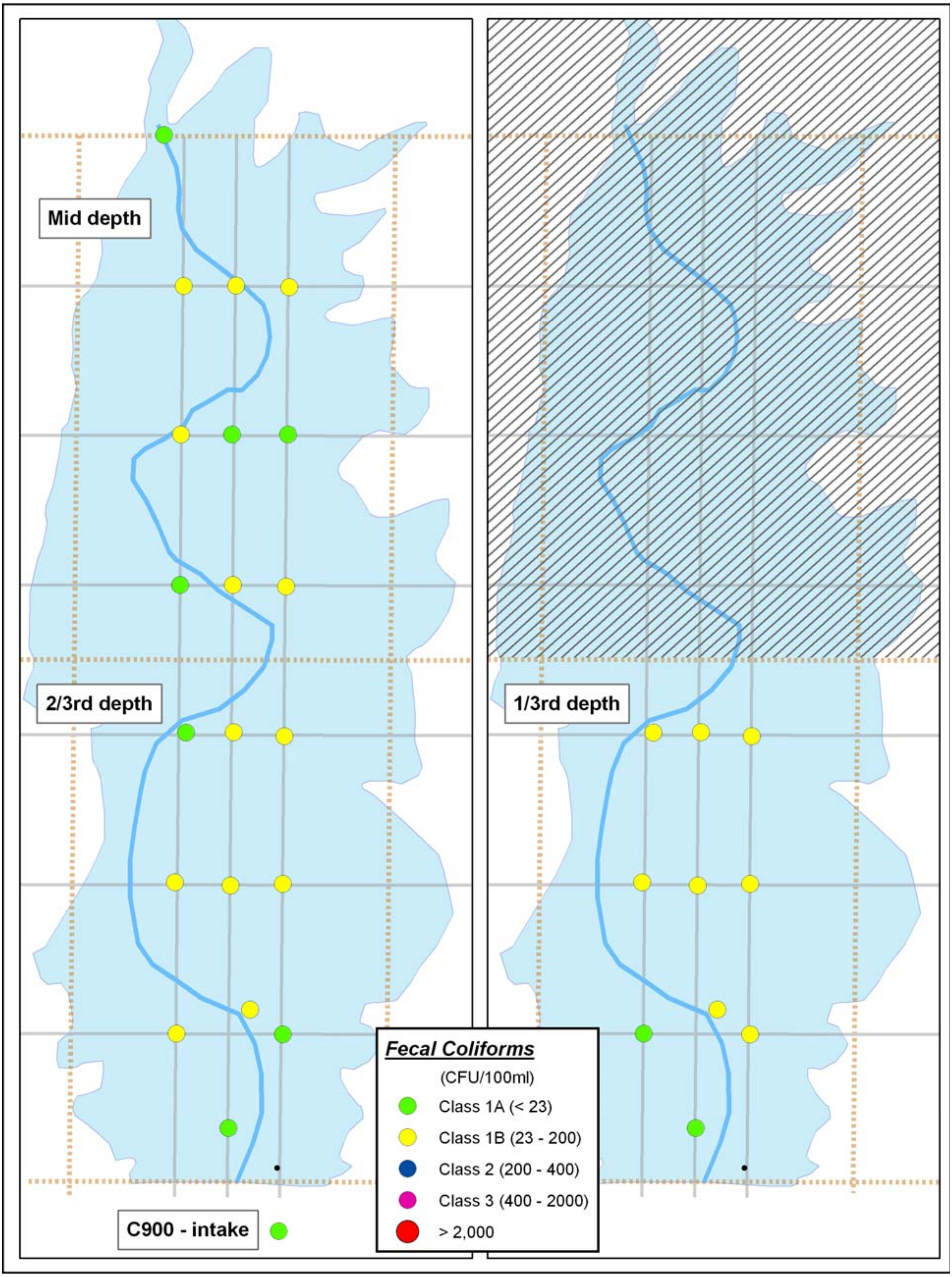


Figure 22. Analysis results of samples from the Qaraoun Lake (Fecal coliform) based on the classes of the proposed Lebanese MoE water quality guidelines for irrigation

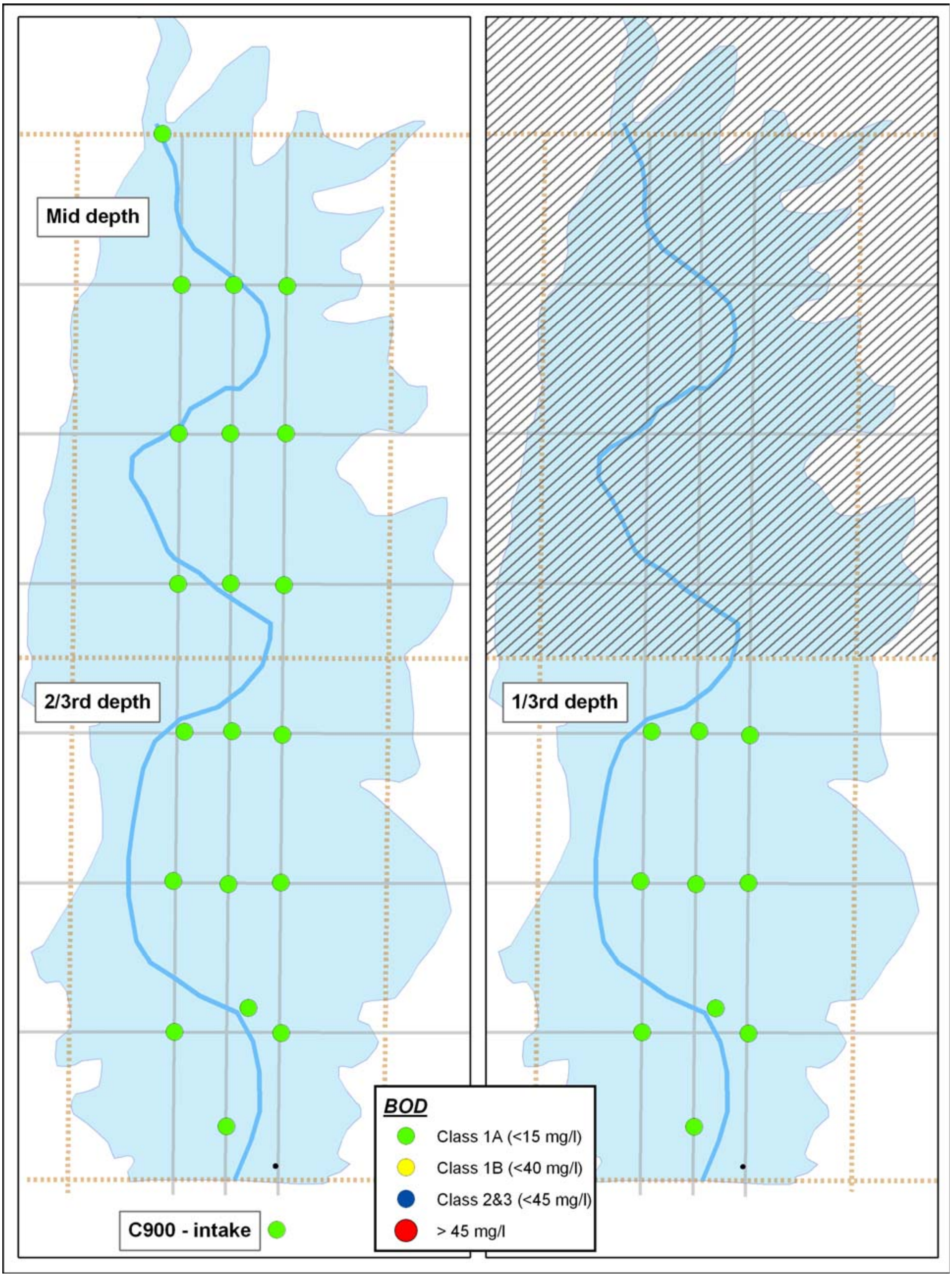


Figure 23. Analysis results of samples from the Qaraoun Lake (BOD) based on the classes of the proposed Lebanese MoE water quality guidelines for irrigation

3.2.3 Canal 900

Few samples from Canal 900 (2 samples out of 13[1]) exhibited fecal coliform levels exceeding the threshold set for all irrigation classes proposed by the reclaimed wastewater guidelines for irrigation of the Lebanese Ministry of Environment (Figure 24), whereas all samples were within the BOD thresholds for all classes (Figure 25). As such, the overall quality of the water in Canal 900 at the time of sampling appeared to be acceptable for irrigation.

When compared to the MoE drinking water quality standards for domestic use, total and fecal coliforms levels in 9 and 13, respectively, of the 13 water samples collected from Canal 900 exceed these standards (Figure 24), while only one of the samples has nitrate levels slightly exceeding these standards. The levels are consistent with the lake and river water quality. Note that samples from Canal 900 were collected nearly one to two months after the river and lake water samples because the Canal was initially empty and pumping was initiated late during the sampling program.

[1] One sample out of 14 is considered an outlier with a significantly high total coliform level probably due to an incidental animal source due to the open nature of the Canal for a considerable length.

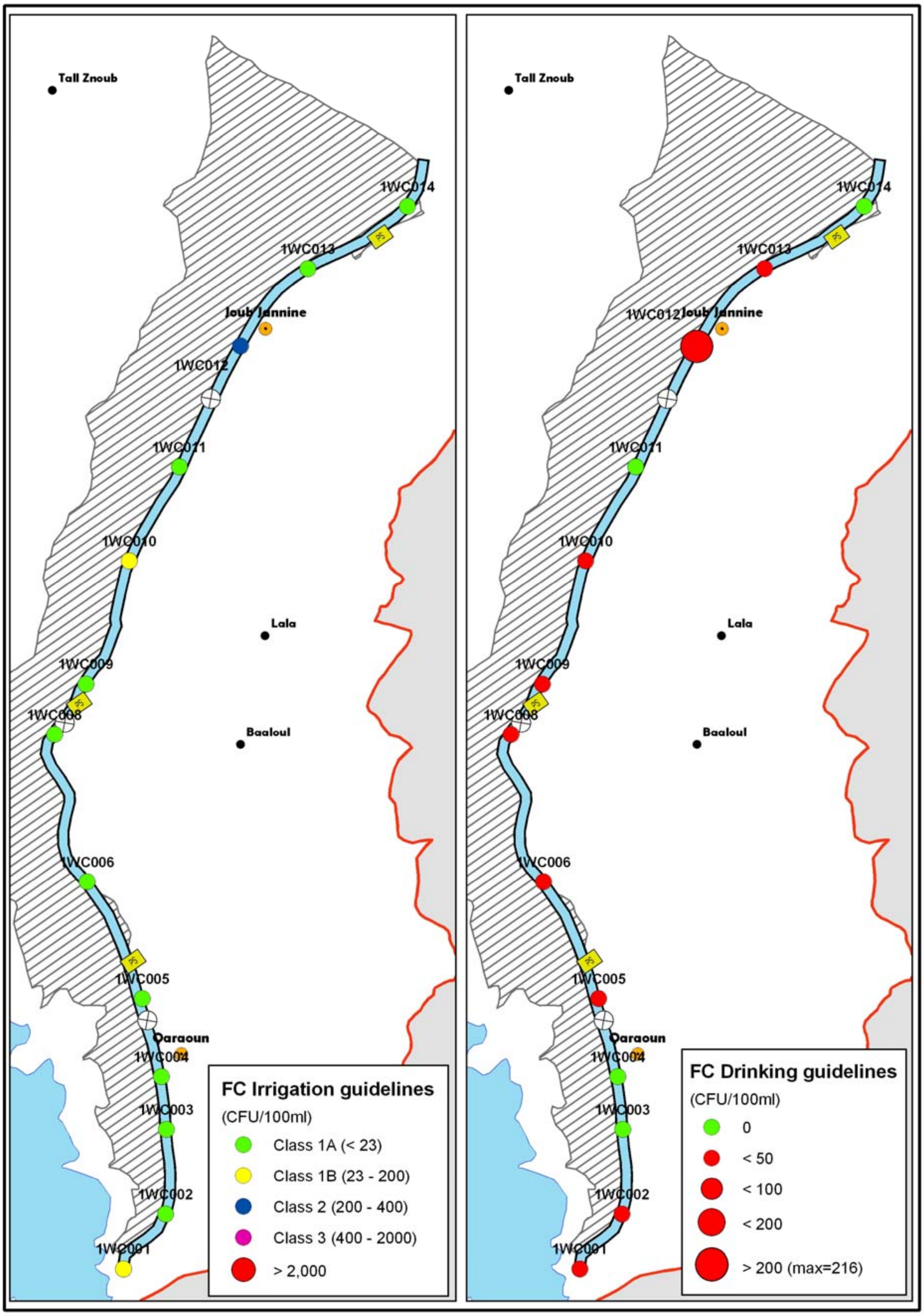


Figure 24. Analysis results for samples collected from Canal 900 (Fecal coliforms)

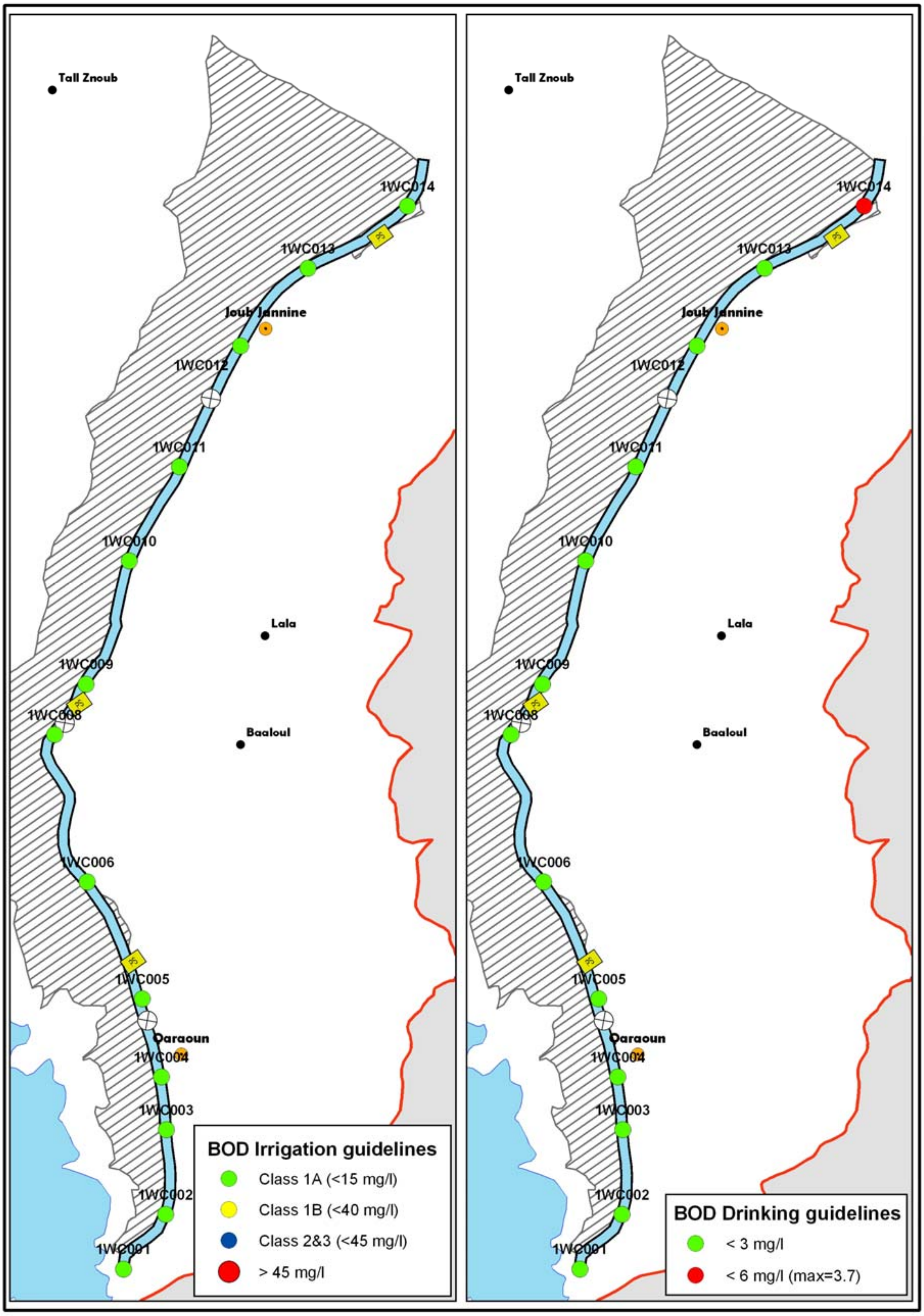


Figure 25. Analysis results for samples collected from Canal 900 (BOD)

3.2.4 Groundwater

Groundwater samples exhibited acceptable levels for most indicators when compared to applicable drinking water standards. Pesticides, namely organo-chlorines and organo-phosphates, were below the detection limits in all samples. (organochlorines < 0.005 mg/L; organophosphates < 0.15 mg/L). This can be attributed to several factors, including 1) the limited application of pesticides during the winter season, 2) the biodegradability of these pesticides in the upper root zone thus not allowing them to reach the groundwater, 3) the relatively thick cover of the Quaternary-Neogene alluviums providing a deep vadoze zone of approximately 70 to 100 m before reaching the water table, and 4) the winter dilution effect. Similarly for almost all tested heavy metals, including Nickel, Copper, Lead, Mercury, Cadmium, and Chromium, the levels were below the detection limits which are below the MoE drinking water standards, except for Zinc, which exceeded the standards at three wells, one located near a gas station. This reflects a limited impact of industries on groundwater quality in the area during the winter season.

On the other hand, total and fecal coliform levels exceeded the MoE drinking water standards in 63 and 23 percent of the sampled wells, respectively (Figure 26). The highest concentrations of total and fecal coliform are observed mainly downstream of Majdel Anjar (boreholes 1KG030, 1KG030) and Joub Jannine (borehole 1KG082), where the Neogene-Quaternary cover is very shallow and the Eocene is almost exposed (Figure 27). Between Dalhamieh and Bar Elias (borehole 1kG015), there is no obvious reason for the propagation of pollution in the aquifer. High total and fecal coliform levels can be attributed to wastewater discharge practices in the area, including non-maintained septic tanks and open discharges. As for nitrate levels, they exceeded the MoE drinking water standards in 77 percent of the sampled wells. The unpolluted boreholes are located at the border of the Bekaa valley (Figure 28). These unpolluted boreholes are fed from the water Barouk/Sannine aquifers before it gets polluted by the anthropogenic activity in Bekaa. High nitrate levels are mostly attributed to common agricultural practices and the heavy application of fertilizers which accumulate in the soil during the summer season and are flushed down to the groundwater during the rainy winter season. Nitrates may also be the by-product of transformed nitrogenous compounds (in sewage, industrial and packing house wastes, drainage from livestock feeding areas and farm manures) that reach the groundwater. Conversely, phosphate reacts with soil constituents to form insoluble compounds that are immobile in soils and consequently poses less threat to groundwater (Figure 28). High levels of nitrates and fecal coliforms in drinking water are associated with health risks, such as the blue baby syndrome (methemoglobinemia) in the case of nitrates and gastrointestinal diseases in the case of fecal coliform (i.e. diarrhea, typhoids).

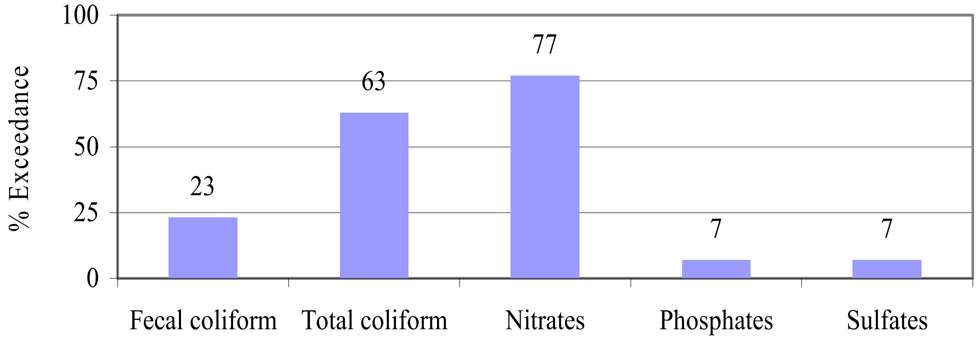


Figure 26. Percentage of groundwater samples exceeding water quality standards

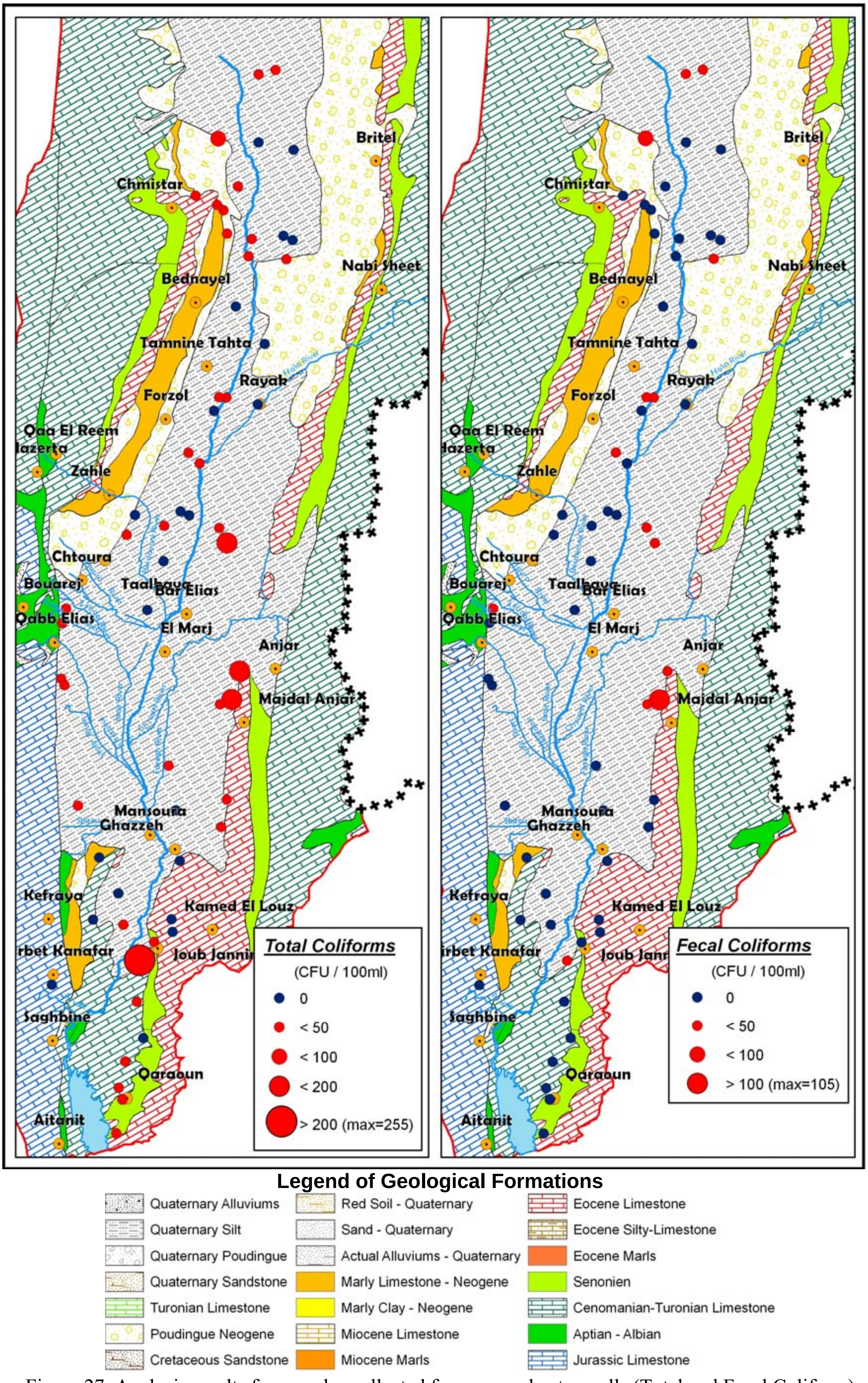


Figure 27. Analysis results for samples collected from groundwater wells (Total and Fecal Coliform)

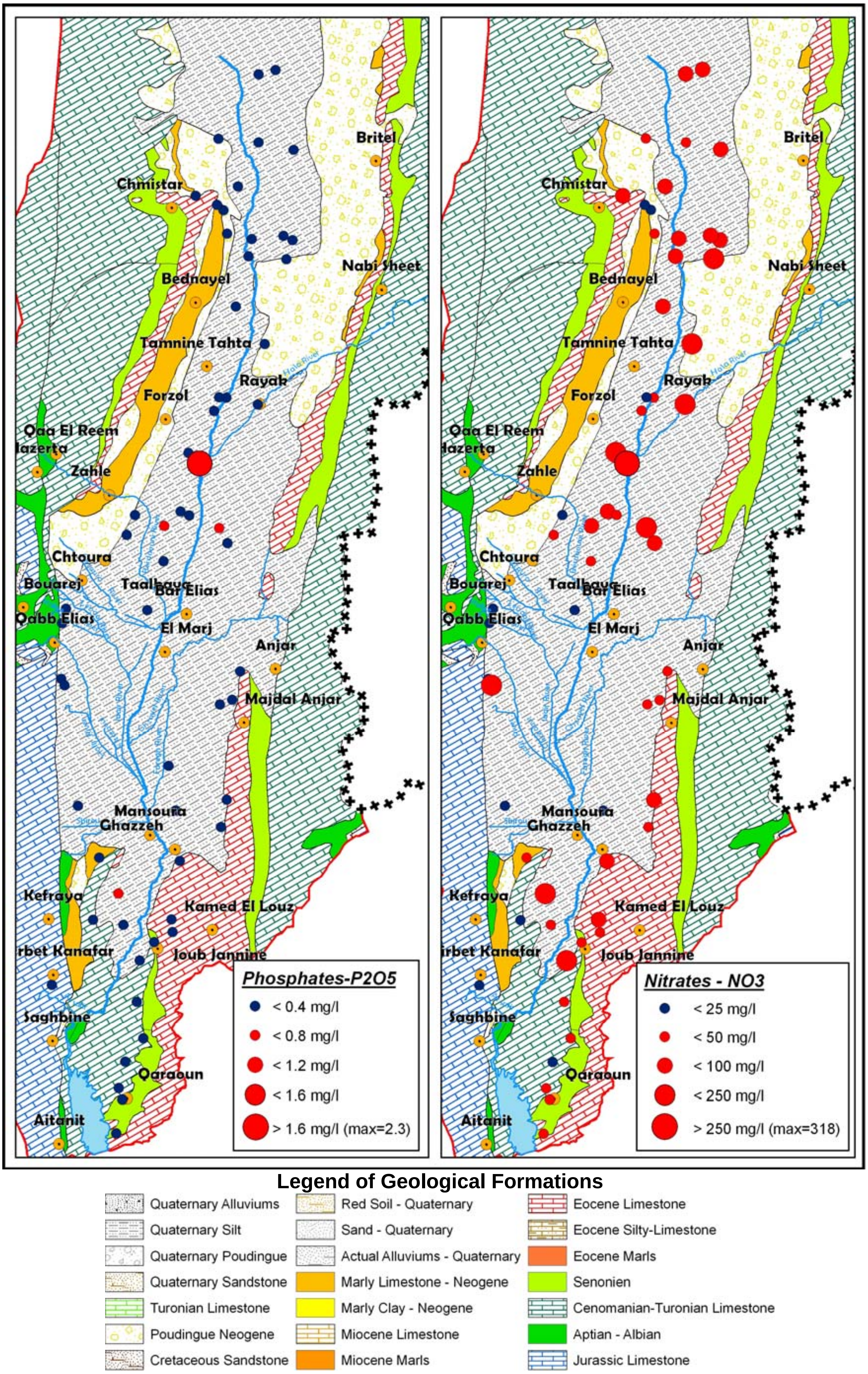


Figure 28. Analysis results for samples collected from groundwater wells (Phosphates and Nitrates)

3.2.5 Water samples comparative assessment

The laboratory analysis indicated that the highest bacteriological (TC, FC, BOD and COD) contamination was measured in river water samples (Table 5). This is due to the proximity of the sample location from the discharger points of untreated wastewater. On the other hand, groundwater levels exhibited the highest levels of nitrates due to the flushing effect of infiltrating water. In contrast, surface water exhibited lower nitrate levels due to the absence of agriculture water return during the winter season, as well as the greater surface water dilution. While the dilution effect decreased the contamination levels considerably to levels acceptable for irrigation in selected classes, the concentrations of several indicators in many lake and canal samples remained above domestic use guidelines.

Table 5. General comparison of water analysis results for various sample types

Indicator	*River (94 samples including springs and sources)*			*Lake (30 samples)*			*Canal 900 (13 samples)*			*Ground water (60 samples)*			*Drinking water standard*			*Reclaimed WW for irrigation*
													MoE-Lebanon		*USEPA*	
	Min.	*Avg.*[3]	*Max.*	*Min.*	*Avg.*[3]	*Max.*	*Min.*	*Avg.*[3]	*Max.*	*Min.*	*Avg.*[3]	*Max.*	*GV*[1] *(20 °C)*	*GV*[1] *(25 °C)*	*GV/MAL*[2]	*MoE guidelines*
pH (pH units)	6.8	7.59	8.18	6.82	7.58	7.78	7.07	7.50	7.99	6.41	6.85	7.5	6.5-8.5	6.5-8.5	6.5-8.5	
Temperature (°C)	4.1	12.39	17.7	11.3	12.52	16	12.9	16.75	21.2	11.6	17.26	20.1	12	NA[4]	NA	
DO (mg/l O_2)	3.95	7.94	9.73	6.45	7.59	8.68	3.2	9.15	15.44	-	-	-	NA	NA	NA	
TDS (mg/l)	114	202.2	415	211	226.8	239	222	238.4	257	-	-	-	400[5]	500[6]	500[6]	
NH_4 [7] (mg/l)	<0.01	1.12	11.01	0.52	0.62	0.7	0.11	0.30	0.47	-	-	-	0.05	NA	NA	
P_2O_5[8] (mg/l)	0.01	0.31	2.01	0.19	0.22	0.33	0.01	0.21	0.4	<0.01	0.12	2.3	0.4	NA	NA	
NO_3^- (mg/l)	<1.0	13.57	49.7	16.2	27.9	34.1	16.8	20.7	25.1	1	60.32	318	25	10 (as N)	10 (as N)	
SO_4^{2-} (mg/l)	<7	19.65	115	34	39	43	32	36.8	44	7	39.08	250	25	250	250	
BOD (mg/l)	0	6.57	45	<2	2.1	3	<2	3.7	2.1	-	-	-	NA	NA	NA	10-45
COD (mg/l)	0	14.73	116	<2	3.87	10	<2	4	15	-	-	-	NA	NA	NA	
FC (CFU[9]/100,ml)	0	20,122	120,000	6	39	196	0	27	216	0	4	105	0	0	0	5-2,000
TC (CFU[9]/100,ml)	0	22,216	120,000	23	64	208	12	617	2900	0	18	255	0	0	0	

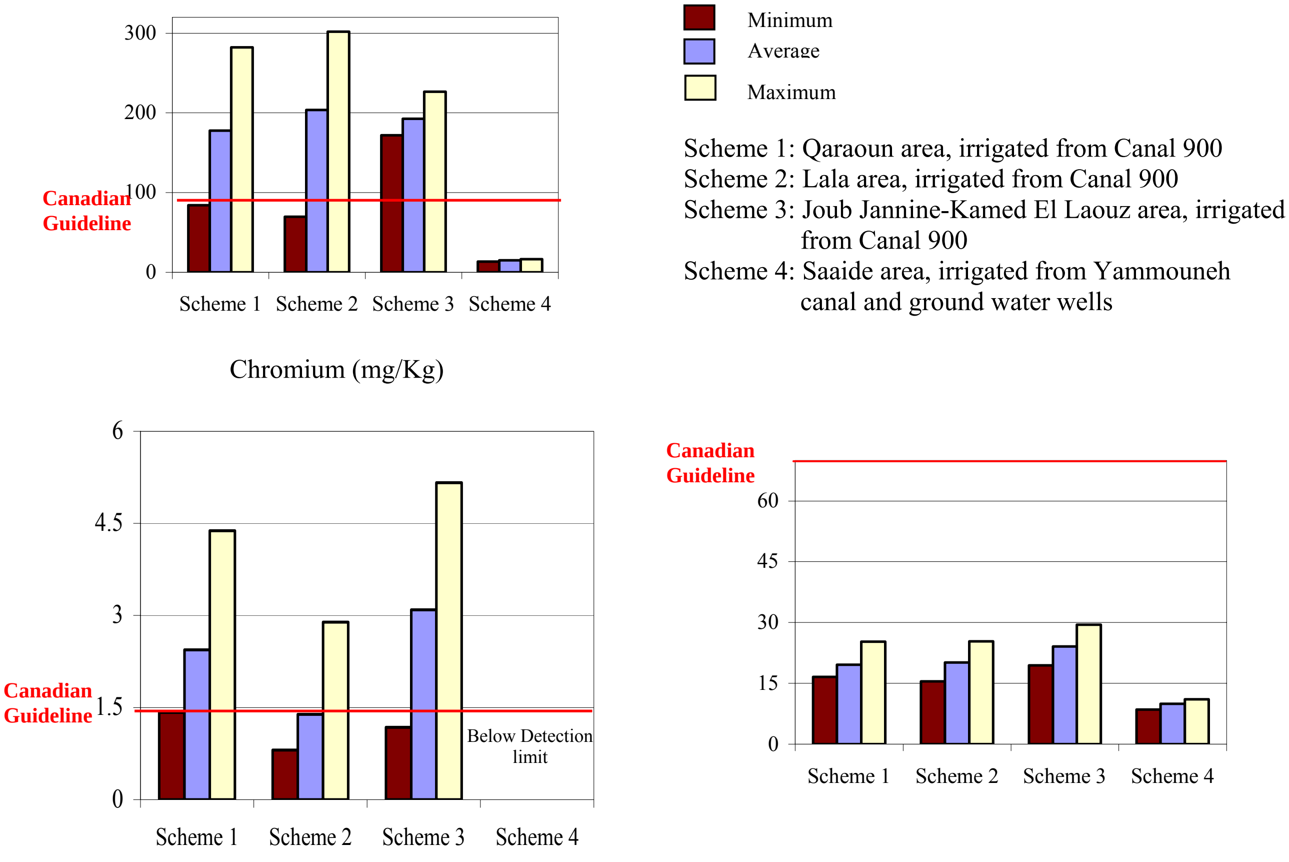
[1] GV: Guideline value
[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency
[3] All values reported < a certain value are set equal to that value when calculating the average
[4] NA: Not applicable
[5] reference temperature at 20°C
[6] reference temperature at 25°C
[7] Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used ($NH_4 = NH_3*1.0588$)
[8] Initial value reported is o-PO_4^{3-}, for comparison a conversion factor of 0.743 was used (P_2O_5 = o-PO_4^{3-} *0.743)
[9] CFU: colony forming unit

3.2.6 Soil

The soil chemical analysis results were compared to the Canadian environmental quality guidelines (Table 6). Chromium levels in soil samples from the three zones of the Canal 900 irrigation schemes (1-Qaraoun area, 2-Lala area, and 3-Joub Jannine-Kamed El Laouz area) exceeded the Canadian guideline for agricultural use by more than two to three folds (Figure 29), with average concentrations of 177.7, 203.8, and 192.7 mg/kg in scheme 1, 2, and 3, respectively compared to the average guideline of 64 mg/kg. Conversely, chromium levels in samples from irrigation scheme 4 (irrigated from the Yammouneh canal and groundwater wells) were within acceptable limits. Lead was detected in all samples at levels below the Canadian guidelines. As for Cadmium, all samples collected from schemes 1 and 3 were above the Canadian guideline, with an average concentration of 2.4 and 3.1 mg/kg for schemes 1 and 3, respectively compared to the average guideline of 1.4 mg/kg. In contrast, levels detected in samples from schemes 2 and 4 were below the guideline. The source of the metals in the soil is not evident particularly that the lake water samples did not exhibit high levels during the winter sampling program but could be explained by the accumulation process of several irrigation cycles. Furthermore, no industrial activity was located in the vicinity of Canal 900 area to ascertain the source of Cadmium and Chromium in the soil. The potential other sources include natural background as well as traces in agrochemicals that may be used in the area. The dry season sampling program may shed light on the potential sources. Phosphate levels were generally higher in soil samples collected from Schemes 1, 2 and 3 (47.4 to 174.5 mg/kg) in comparison to samples collected from Scheme 4 (43.7 to 78 mg/kg) indicating a potential phosphorous buildup as a result of irrigation with water laden with relatively greater phosphate concentrations. The opposite pattern was observed for Ammonia-N (Figure 30) whereby levels from Schemes 1, 2 and 3 (7.9 to 93.0 mg/kg) were lower in comparison to levels detected in samples collected from Scheme 4 (9.8 to 110.8 mg/kg) indicating a potential excessive localized application of fertilizers in the Yammouneh area. Additional comparative analysis with soil samples from other locations as well as with international standards is on-going to assist in understanding the implications of the recorded levels. The analysis results of all soil samples are presented in Appendix H.

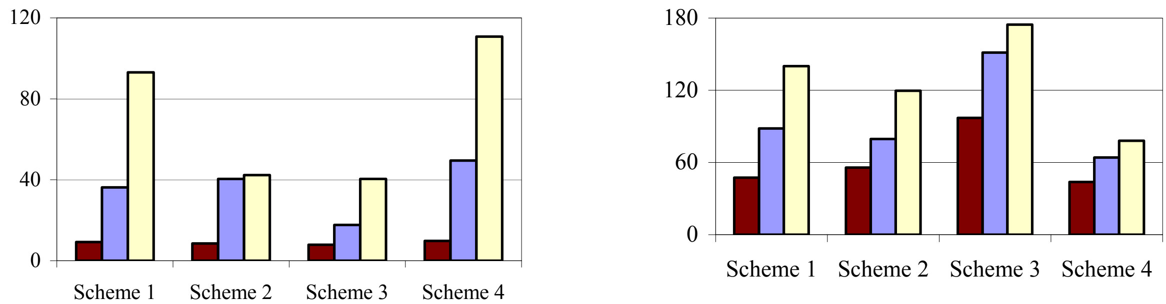
Table 6. Canadian environmental quality guidelines for soil (NGSO, 2005)

Parameter	*Agriculture use*
Chromium (mg/kg)	64
Lead (mg/kg)	70
Cadmium (mg/kg)	1.4



Cadmium (mg/kg) Lead (mg/kg)

Figure 29. Heavy metal analysis results of soil samples



Ammonia-N (mg/kg) Phosphate (mg/kg)

Figure 30. Ammonia-N and Phosphate analysis results of soil samples

3.2.7 Lake sediments

Similar to soil samples, Chromium levels in lake Qaroun sediment samples ranging between 319.7 and 633.3 mg/kg were detected thus exceeding the Canadian Interim Sediment Quality

Guideline (ISQG[1]) of 37.3 mg/kg by nearly 10 to 20 folds as well as the Probable Effect Level (PEL) of 90 mg/kg (Table 7 and Figure 31). Conversely, Lead levels were generally below the Canadian ISQG of 35 mg/kg with the exception of one sample that exhibited a slightly higher value of 38 mg/kg. On the other hand, Cadmium levels (0.87 to 3.47 mg/kg) exceeded the ISQG of 0.6 mg/kg but were lower than the PEL of 3.5 mg/kg. Phosphate and Ammonia-N levels ranged between 32.8 to 187.2 mg/kg and below detection limit to 277.9 mg/kg, respectively. Both ranges are higher than their counterparts reported above for the soil samples. Additional comparative analysis with sediment samples from other locations as well as with international standards is on-going to assist in understanding the implications of the recorded levels. The analysis results of sediment samples from the Qaraoun Lake are presented in Appendix H.

Table 7. Canadian environmental quality guidelines for freshwater sediments (NGSO, 2005)

Parameter	*Fresh water sediment*	
	ISQG[1]	*PEL[2]*
Chromium (mg/kg)	37.3	90
Lead (mg/kg)	35	91.3
Cadmium (mg/kg)	0.6	3.5

[1] Interim sediment quality guideline
[2] Probable effect level

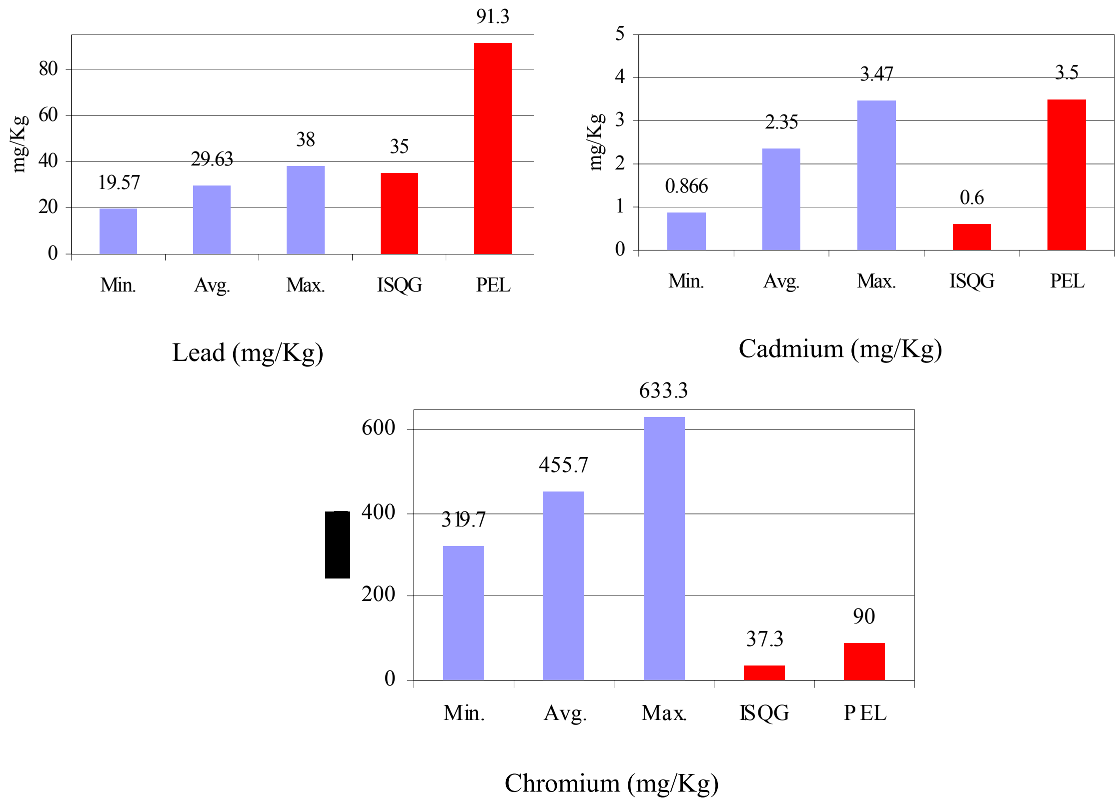


Figure 31. Analysis results of sediment samples from Lake Qaraoun

[1] The CISQG and the PEL are used in risk assessment studies by toxicologists and epidemiologists to reflect different levels of risk when exposed to a certain concentration. They come mostly from dose-response studies and often reflect a certain uncertainty because of the lack of exposure data or because of extrapolations from laboratory data often obtained from animal exposure at high dosages with respect to their body weight in comparison with human weight. They are mostly used as indicators to reflect the level of potential risk.

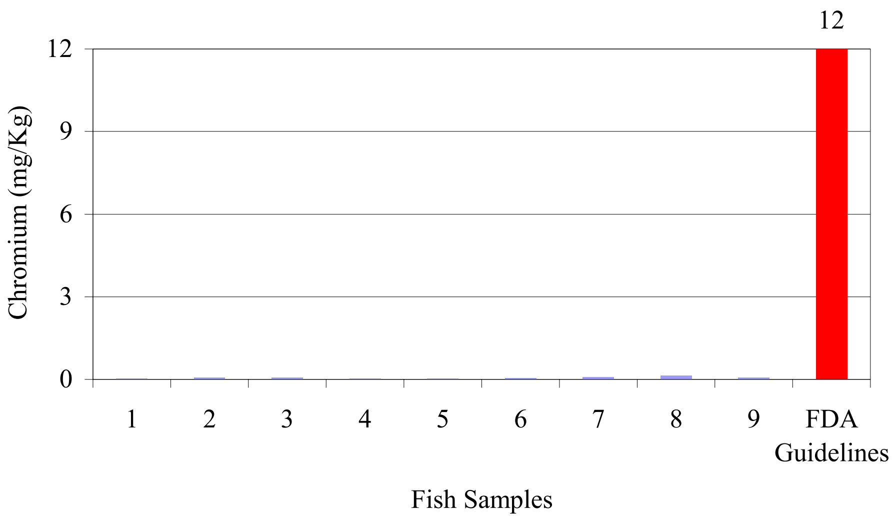
3.2.8 Fish

The fish samples (7 fishes) collected from the Qaraoun lake ranged between 25 and 43 cms in length, and 150 and 760 g in weight. The analysis was conducted on tissue from each fish (7 samples). Moreover, a composite sample from the gills of samples 6 and 7, and a composite sample from the entire sample 7 were also analyzed. Heavy metals were detected in all samples (Table 8) with levels ranging between 0.035 and 0.125 mg/kg (average = 0.059 mg/kg) for Chromium, 0.03 and 70.16 mg/kg (average = 8.86 mg/kg) for Cadmium, and 0.006 and 1.84 mg/kg (average = 0.25 mg/kg) for Lead.

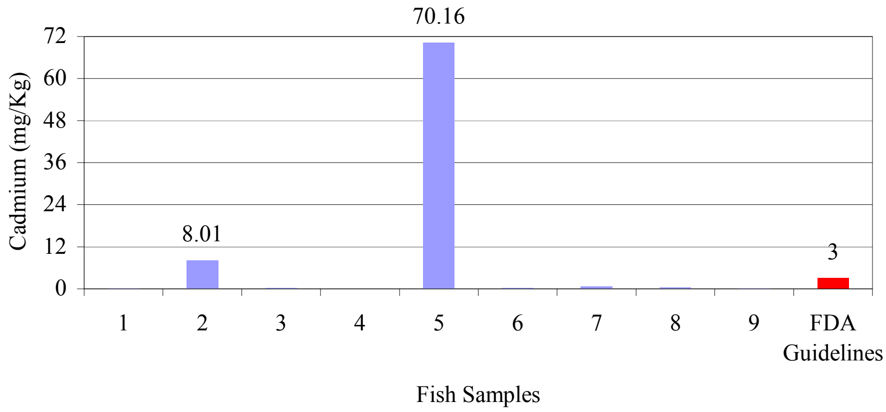
Table 8. Analysis results of fish samples from Lake Qaraoun

Fish	*Length (cm)*	*Weight (g)*	*Chromium (mg/Kg)*	*Cadmium (mg/Kg)*	*Lead (mg/Kg)*
1	25	150	0.035	0.107	0.013
2	27	183	0.060	8.012	0.081
3	26	155	0.063	0.140	0.112
4	26.8	165	0.040	0.030	0.009
5	25.5	134	0.036	70.157	0.027
6	43	760	0.045	0.173	0.006
7	26	155	0.078	0.670	1.843
Composite samples					
8	Gills from samples 6 and 7		0.125	0.379	0.086
9	From the whole of Sample 7		0.053	0.101	0.089
Detection Limit			0.002	0.125	0.379

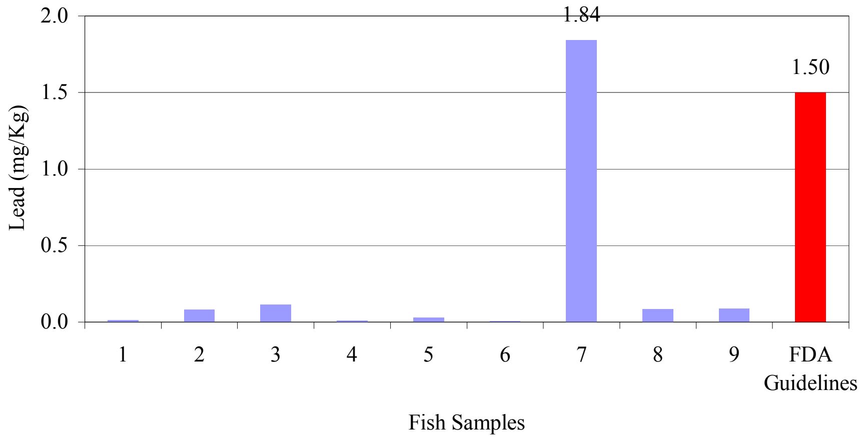
The measured results revealed that chromium levels in the sampled fish are significantly below the Food and Drug Administration (FDA) Levels for Toxic Elements in Fish, while cadmium and lead levels exceed the FDA guidelines for two and one samples respectively (Figure 32). Concentrations of heavy metals in fish may be indicative of the degree of probable bioaccumulation and biomagnification of the levels of heavy metals in the Qaraoun water, whereby the latter were insignificant and below detectable levels.



Chromium (mg/Kg)



Cadmium (mg/Kg)



Lead (mg/Kg)

Figure 32. Analysis results of fish samples from Lake Qaraoun

4. SURVEY OF WWTPS

As recommended by the Rapid Review (RR), information related to existing and planned Wastewater Treatment Plants (WWTPs) in the Upper Litani Basin were updated based on the master plan approved by the Ministry of Energy and Water (MEW) and the Council for Development and Reconstruction (CDR), and an ongoing initiatives particularly the program funded by the United States Agency for International Development (USAID) for the study and design of WWTPs in the Upper Litani Basin under a contract with Camp, Dresser & McKee (CDM).

In the CDR-MEW master plan, the Upper Litani Basin is divided into 7 catchments (Qaraoun, Saghbine, Joub Jannine, El-Marj, Zahle, Timnine El Tahta, and Baalbeck). Each catchment is served by a WWTP that treats the wastewater generated from the villages within the catchment, and the treated effluent will be discharged into the Litani river or its tributaries (Figure 33). In this context, it is worth noting that the WWTP of Baalbeck is also planned to serve villages located outside the boundaries of the Upper Litani Basin, namely Younine, Nahle Tfail, Ham, and Maaraboun areas as depicted in Figure 33. Table 9 summarizes the proposed and planned WWTPs as approved in the CDR-MEW master plan, including WWTP location, number of villages and population served, design flow, treatment technology, and construction cost and funding agency.

On the other hand, the USAID funded program is addressing 2 of the 7 catchments mentioned earlier, namely Qaraoun and Tamnine El Tahta. While in the Qaraoun catchment, the planned USAID treatment plant is consistent with the CDR-MEW approved master plan, in Tamnine El Tahta catchment, CDM proposed 7 different WWTPs to serve the towns and villages within this catchment and its surrounding area. The WWTPs defined in the CDM contract are depicted in Figure 34 and described briefly in Table 10. Whereas both plans (CDR-MEW and CDM) target wastewater management in villages geographically distributed throughout the Upper Litani Basin, a considerable number of villages (46 percent) in which 13.3 percent of the population resides is still not served within their schemes as illustrated in Figure 35 and Table 11.

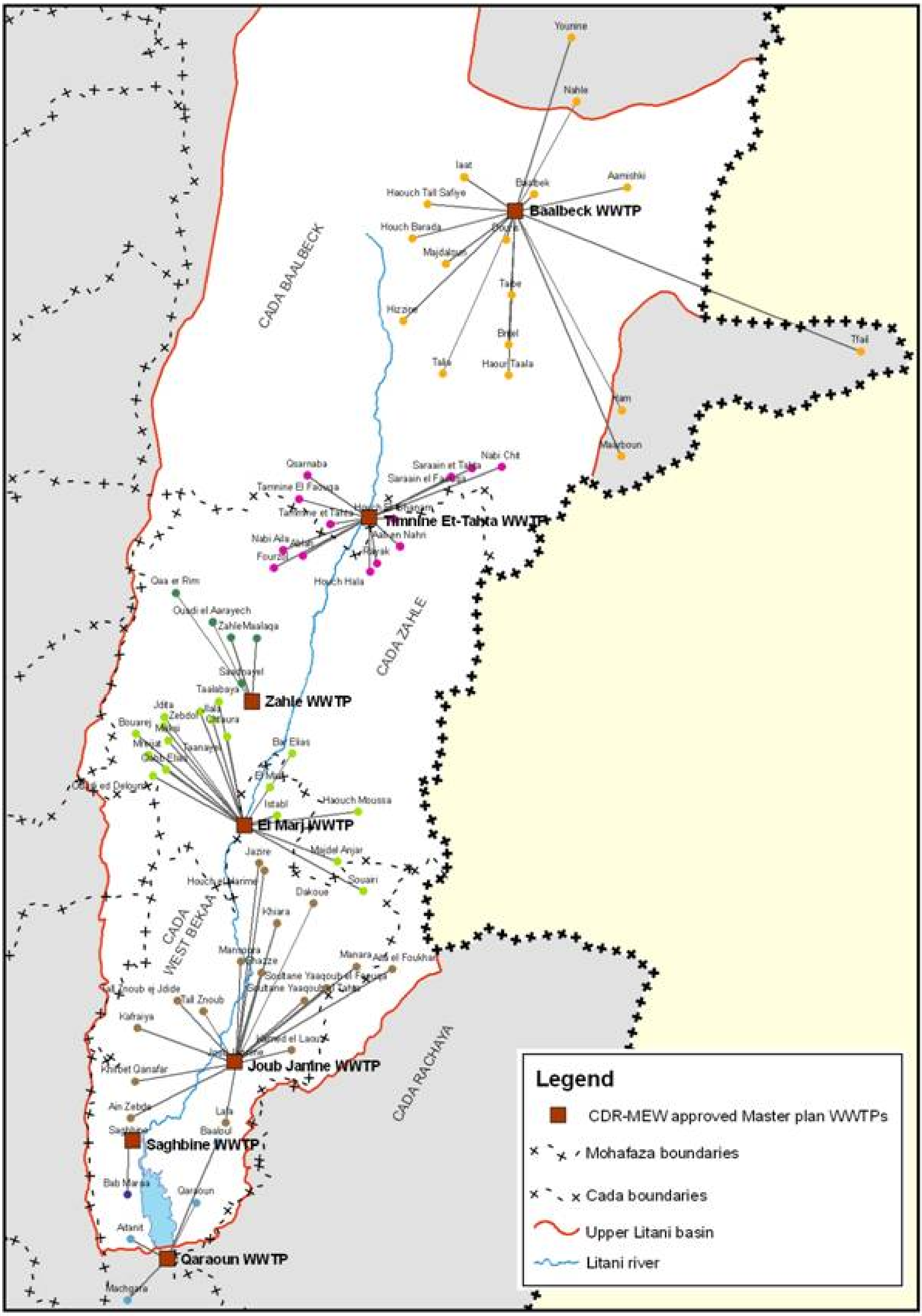


Figure 33. WWTPs in the Upper Litani Basin as proposed by the CDR-MEW approved master plan

Table 9. CDR-MEW master plan for WWTPs in Upper Litani Basin [a]

Treatment plant	*Status*	*Villages served*	*Caza*	*Village*	*Population*	*Design flow (m^3/day)*	*Type of treatment*[b]	*Cost ($x10^6$ USD)*	*Funding agency*
Qaraoun[c]	Proposed	4	West Bekaa	Aitanit	2,477	312	Activated sludge	10	-
				Baaloul	7,110	896			
				Machghara	25,890	3,262			
				Qaraoun	17,338	2,185			
					52,815	**6,655**			
Saghbine[d]	Under construction	2	West Bekaa	Bab Mareh	625	68	Oxidation ditch	7	Islamic bank
				Saghbine	3,475	460			
					4,100	**528**			
Joub Jannine[d]	Under construction	18	West Bekaa	Ain Zebde	990	140	Activated sludge	17	Islamic bank
				Aita El Foukhar	2,168	457			
				Azze	2,165	451			
				Haouch El Harim & El Jazire	3,216	895			
				El Dakoue	240	52			
				El Khiara	640	195			
				Ghazze	5,672	1,240			
				Hammara (Manara)	2,565	607			
				Joub Jannine	8,167	2,044			
				Kamed El Laouz	5,689	1,208			
				Kefraya	1,382	284			
				Khirbet Qanafar	3,275	738			
				Lala	2,779	680			
				Mansoura	1,651	348			
				Sultan Yacoub El Faouqa	689	153			
				Sultan Yacoub El Tahta	1,891	437			
				Tell Znoub	118	22			
				Tell Znoub Ej Jdide	415	74			
					43,712	**10,025**			
El Marj[e]	Under construction	16	Zahle	Aanjar	21,395	3,100	Activated sludge	20	Italian protocol
				Majdel Aanjar	27,968	4,055			
				Saouri	16,226	2,353			
				Barr Elias	45,129	6,544			

Treatment plant	*Status*	*Villages served*	*Caza*	*Village*	*Population*	*Design flow (m^3/day)*	*Type of treatment*[b]	*Cost ($x10^6$ USD)*	*Funding agency*
				El Marj	14,391	2,086			
				Er Raouda	1,823	264			
				Bouerij	5,504	798			
				Chtaura/Jlala	8,270	1,199			
				El Mraijat	8,872	1,286			
				Jdita	20,158	2,923			
				Makse	4,146	601			
				Qabb Elias	50,316	7,296			
				Taalbaya	40,490	5,871			
				Taanayel	3,955	573			
				Wadi Ed Delem	3,667	532			
				Zebdol	2,427	352			
					274,737	**39,833**			
Zahle[f]	Under construction	5	West Bekaa	Qaa Er Rim	1,936	414	Activated sludge	20	Italian protocol
				Ouadi El Arayech	2,087	446			
			Zahle	Zahle	167,787	35,868			
				Maalaqa	48	10			
				Saadnayel	2,383	510			
					174,241	**37,248**			
Tamnine El Tahta[g]	Proposed	12	Zahle	Nabi Chit	8,817	1,884	Activated sludge	10	-
			Baalbeck	Saraain El Fouqa	3,655	689			
				Saraain El Tahta	3,226	781			
				Haouch El Ghanam	408	87			
				Ablah	2,579	551			
				Ali En Nahri	4,516	965			
				Rayak/ Haouch Hala	11,807	2,523			
				Timnine El Tahta	7,420	1,586			
				Timinine El Faouqa	4,086	873			
				Nabi Aila	1,022	218			
				Fourzol	2,579	551			
				Qsarnaba	4,730	1,011			
					54,845	**11,719**			

Treatment plant	*Status*	*Villages served*	*Caza*	*Village*	*Population*	*Design flow (m^3/day)*	*Type of treatment*[b]	*Cost ($x10^6$ USD)*	*Funding agency*
Baalbeck[h]	Existing/not operating	17	Baalbeck	Douris	3,820	539	Oxidation ditch	10	World Bank
				Iaat	4,297	606			
				Nahle	3,183	449			
				Younine	6,367	898			
				Taybeh	1,096	154			
				Majdaloun	312	44			
				Haouch Barada	783	110			
				Haouch Tel Safiya	940	132			
				Britel	5,889	830			
				Hortaala	4,761	671			
				Talia	1,909	269			
				Hezzine	940	132			
				Ham	470	66			
				Maaraboun	940	132			
				Tfail	157	22			
				Baalbeck	51,386	7,245			
				Aamishky	1,411	199			
					88,661	**12,498**			

[a] Sources:

- West Bekaa Wastewater Disposal and Treatment Project – Treatment Plants Design Report, by Bureau Technique Pour Le Development for Ministry of Energy and Water, June 1997.
- West Bekaa Region Wastewater Project – Design Report, by Bureau Technique Pour Le Development for Ministry of Energy and Water, June 1997.
- Complementary Sewage Networks Design, and Wastewater Treatment Plant Project Guide for West Bekaa Wastewater Project, System 1, 2, And 3 – Final Design Report, by Bureau Technique Pour Le Development for CDR and Ministry of Energy and Water, June 2003.
- Economic and Financial Study and Environmental Impact Assessment for Anjar/Majdel Anjar Wastewater Project (Caza of Zahle), by Bureau Technique Pour Le Development for CDR, May 2005.
- Lebanon's Staged Wastewater Program, by Khatib & Alami for Ministry of the Environment, 1995

[b] Secondary treatment
[c] Population estimation for year 2050.
[d] Population estimation for year 2020.
[e] Population estimation for year 2025.
[f] Population estimation for year 2015.
[g] Population estimation for year 2030.
[h] Population estimation for year 2005.

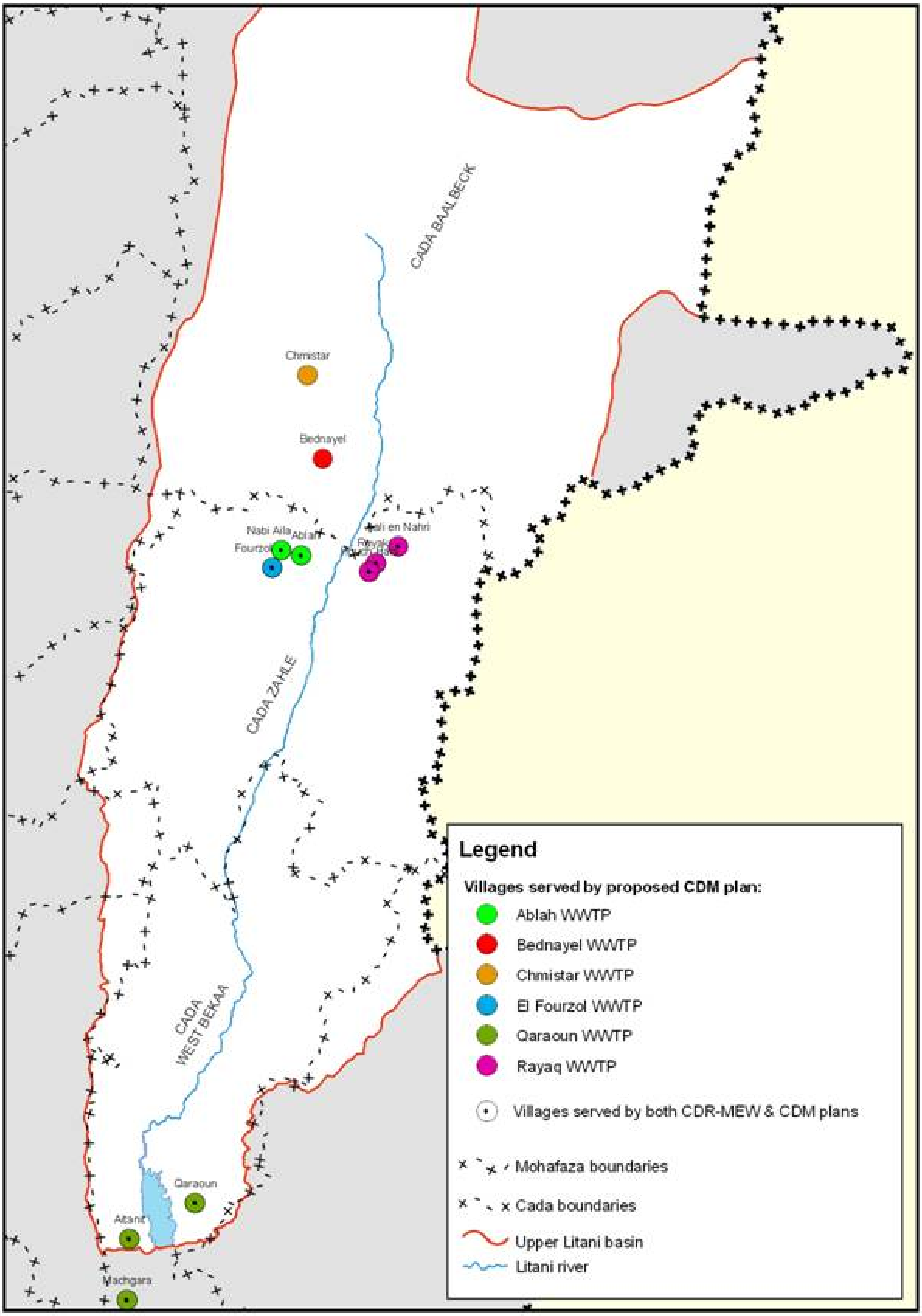


Figure 34. Villages served by proposed USAID funded WWTPs in the Upper Litani basin

Table 10. Characteristics of proposed USAID funded WWTPs in the Upper Litani Basin

WWTP	*Villages served*	*Design Population (2025)*	*Design Flow (m^3/day)*	*Estimated Construction Cost ($)*	*Treatment Type*
Qaraoun	Qaraoun Aitanit Machgara	29,758	4,999	2,192,000	Trickling Filter
Ablah	Nabi Ayla Ablah	8,462	1,363	1,154,000	Trickling Filter
Bednayal	Bednayal	9,580	1,631	1,215,000	Trickling Filter
Chmistar	Chmistar	10,819	1,742	1,078,000	Trickling Filter
El Ferzol	El Ferzol	6,733	978	1,138,000	Trickling Filter
Rayak	Rayak Ali En Nahri Haouch Hala	28,461	4,133	2,092,000	Trickling Filter

Table 11. Percentage of served and unserved villages by the existing plans for wastewater treatment in the Upper Litani River Basin

	Not served		Served		Total
	n	%	n	%	
Village	64	46	75	54	139
Population	62,383	13.3	405,193	86.7	467,559

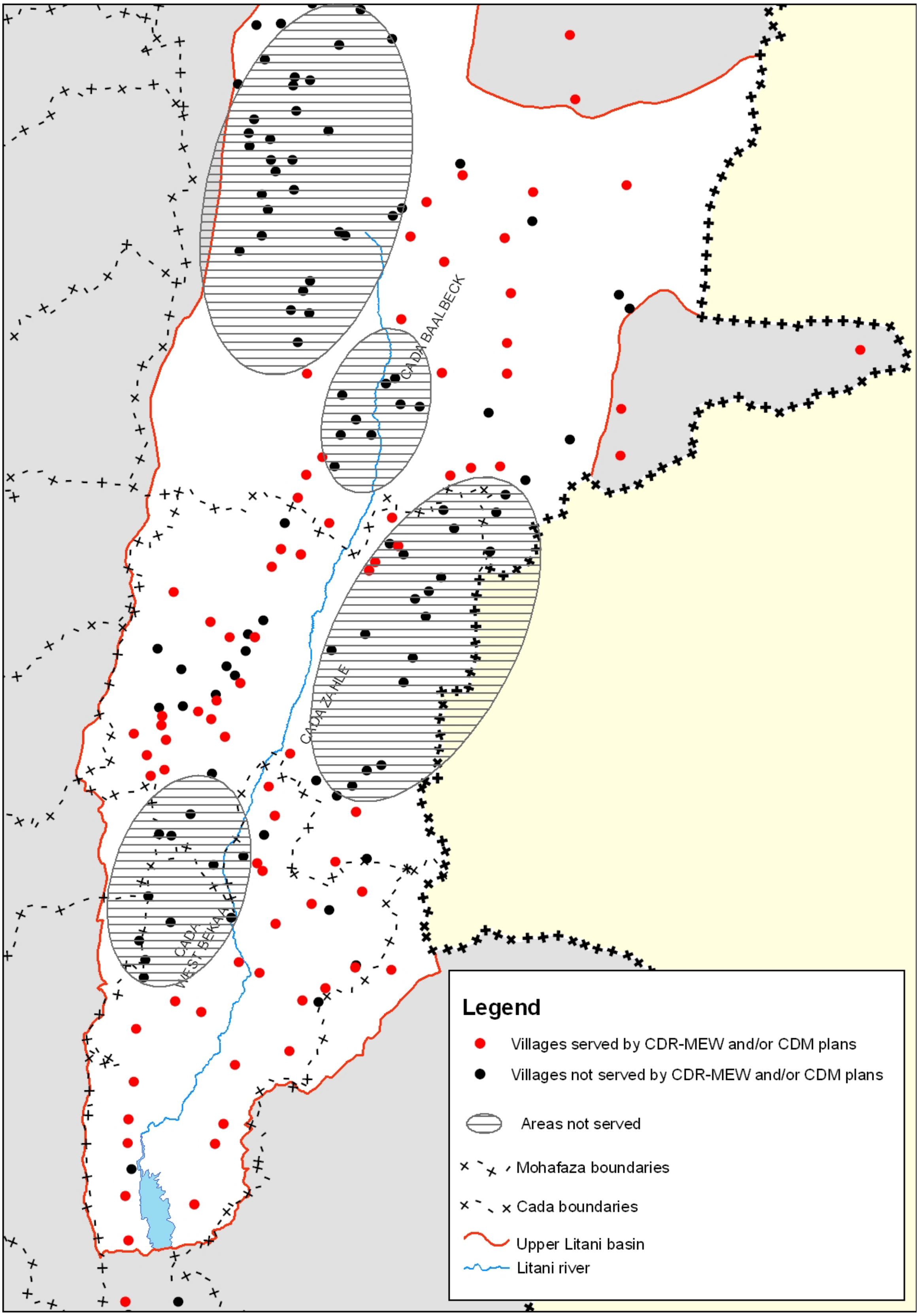


Figure 35. Served vs non-served villages in Upper Litani basin through the CDR-MEW master plan or the proposed USAID funded WWTPs

5. HEALTH SURVEY

The main objective of the field Health Survey is to examine waterborne illnesses associated with degraded water quality in the upper Litani Basin to assess the damage cost of water pollution in the basin for the year 2004. Water pollution has a cost to society. This cost arises primarily on two fronts: 1) due to increased rates of waterborne illnesses and mortality associated with inadequate water sanitation and hygiene (Esrey *et al.*, 1991; Muller and Morera, 1994; WHO, 1996; 1998) which translates into an economic loss in terms of cost of illness and forgone earnings; 2) individuals and communities at risk may incur costs associated with protective measures referred to as averting expenditures such as purchases of bottled water or the incremental cost paid to transport cleaner water from other sources. Most waterborne illnesses have a common symptom, which is diarrhea. Typhoid is an exception. For the purpose of the current health field survey, a questionnaire (Appendix I) was developed specifically for the project and administered at hospitals and dispensaries in the upper Litani river basin including the districts of Baalbek, Zahle and West Bekaa covering a total 46 medical facilities. The distribution of the surveyed facilities in the three districts is shown in Figure 36. About 28 percent of these facilities were hospitals (Figure 37). The geographical distribution of surveyed hospitals and dispensaries throughout the basin is presented in Figure 38.

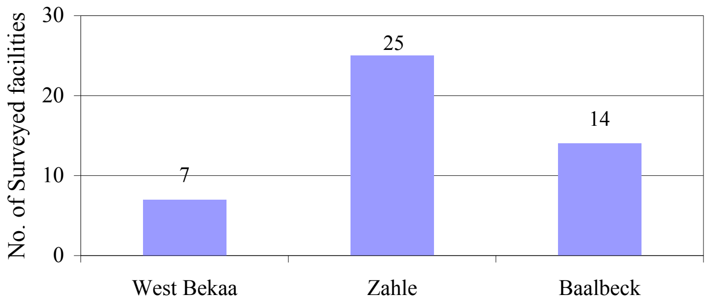


Figure 36. Distribution of the surveyed medical facilities in the three districts

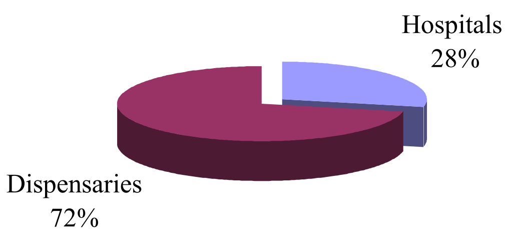


Figure 37. Type of surveyed medical facilities

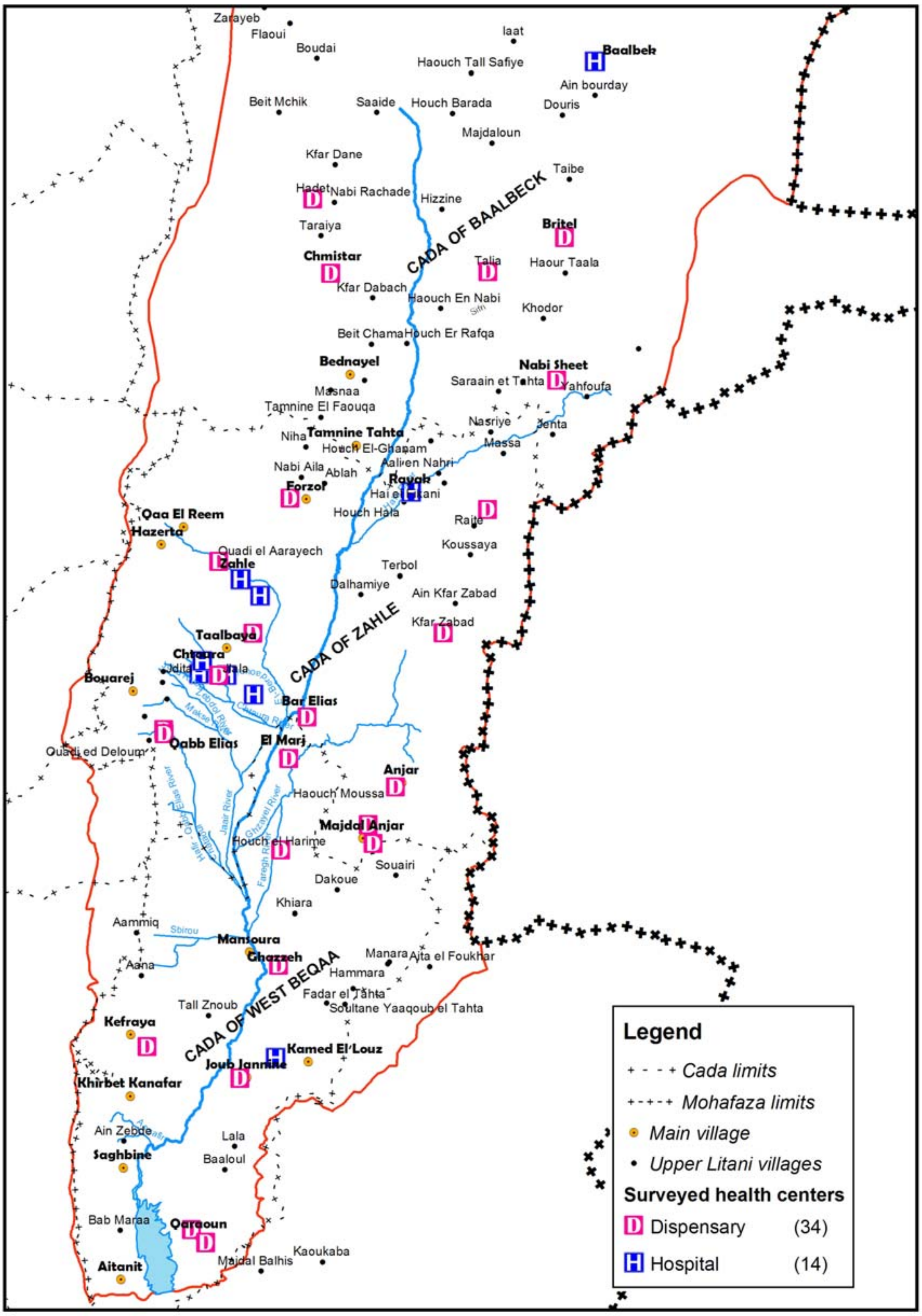


Figure 38. Geographic distribution of surveyed facilities in the upper Litani basin

The survey intended to assess the number of diarrhea and typhoid cases recorded in the medical facilities between January 2004 and January 2005. Around 6,150 cases were examined, the larger part being diarrhea cases (Figure 39). The survey revealed that the highest number of recorded cases is in the district of Zahle (Figure 40). The majority of typhoid cases were recorded in hospitals (Figure 41). Diarrhea and typhoid cases of each surveyed medical facility are presented in Figures 57, 58, and 59. While it appears that each dispensary is serving to a large extent its surrounding area, it seems that hospitals are serving a larger area than their immediate surrounding. While no accurate data were available on the differentiation of recorded cases between children and adults, for each surveyed facility, an estimate was provided by a key administrator working at the facility. The best estimate indicates that nearly 60 percent of recorded diarrhea cases are related to children. In addition, most diarrhea cases recorded at hospitals refer to children.

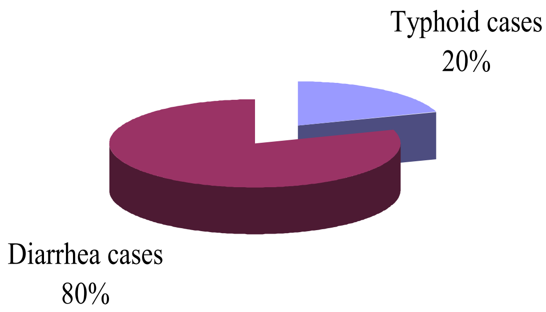


Figure 39. Type of recorded cases

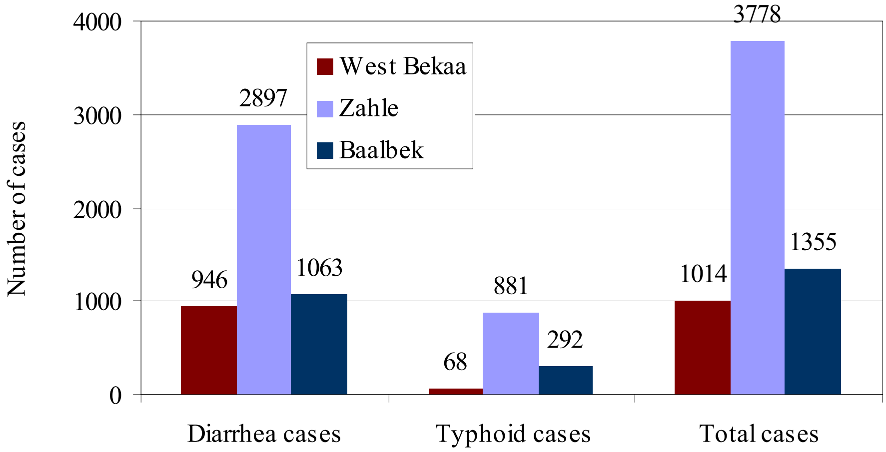


Figure 40. Distribution of recorded cases in the three surveyed districts

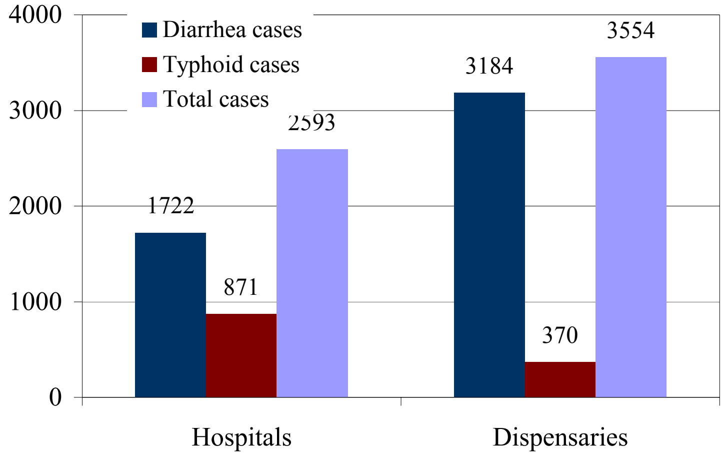


Figure 41. Recorded diarrhea and typhoid cases in surveyed hospitals and dispensaries for the year 2004

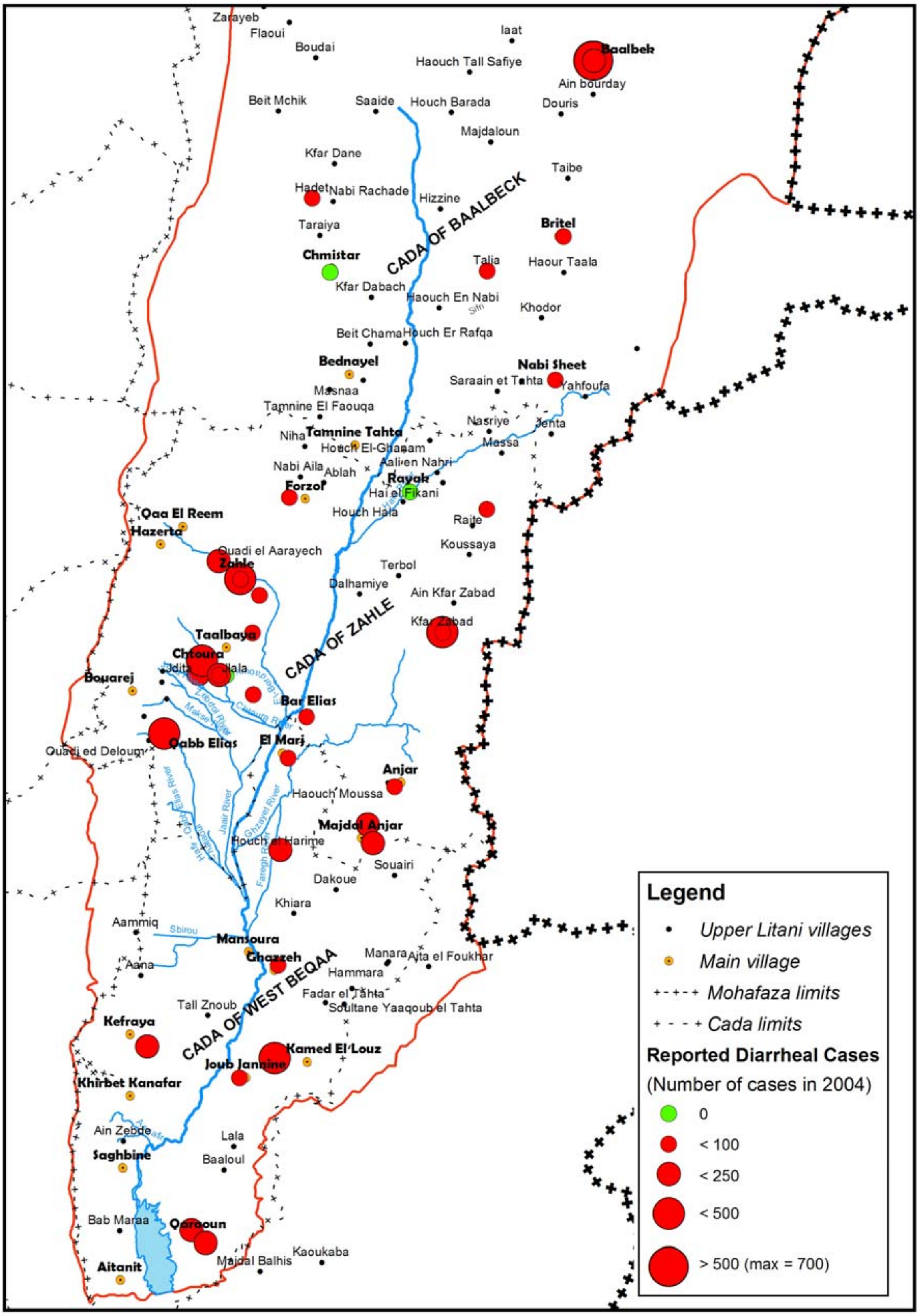


Figure 42. Recorded diarrhea cases in surveyed medical facilities

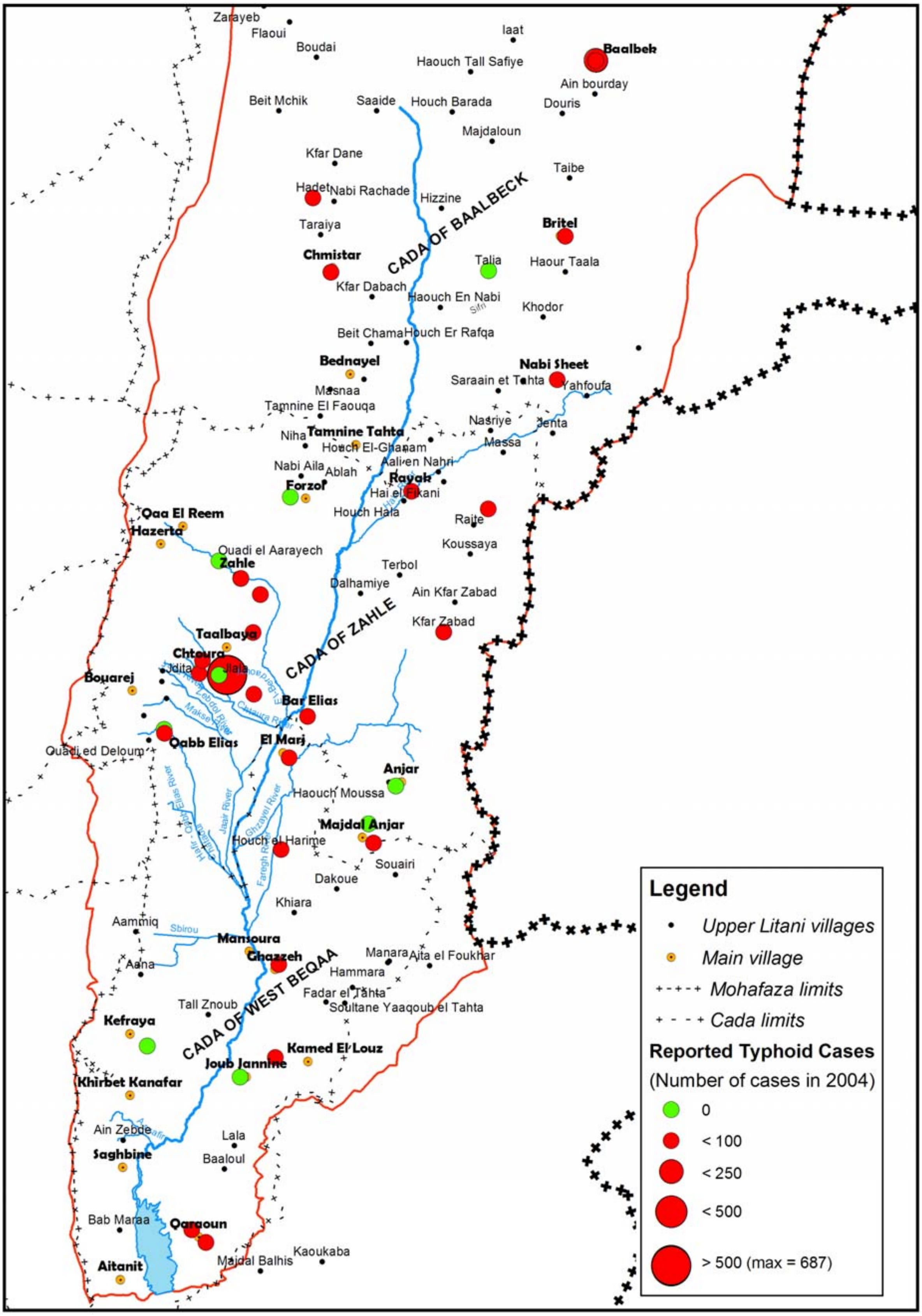


Figure 43. Recorded typhoid cases in surveyed medical facilities

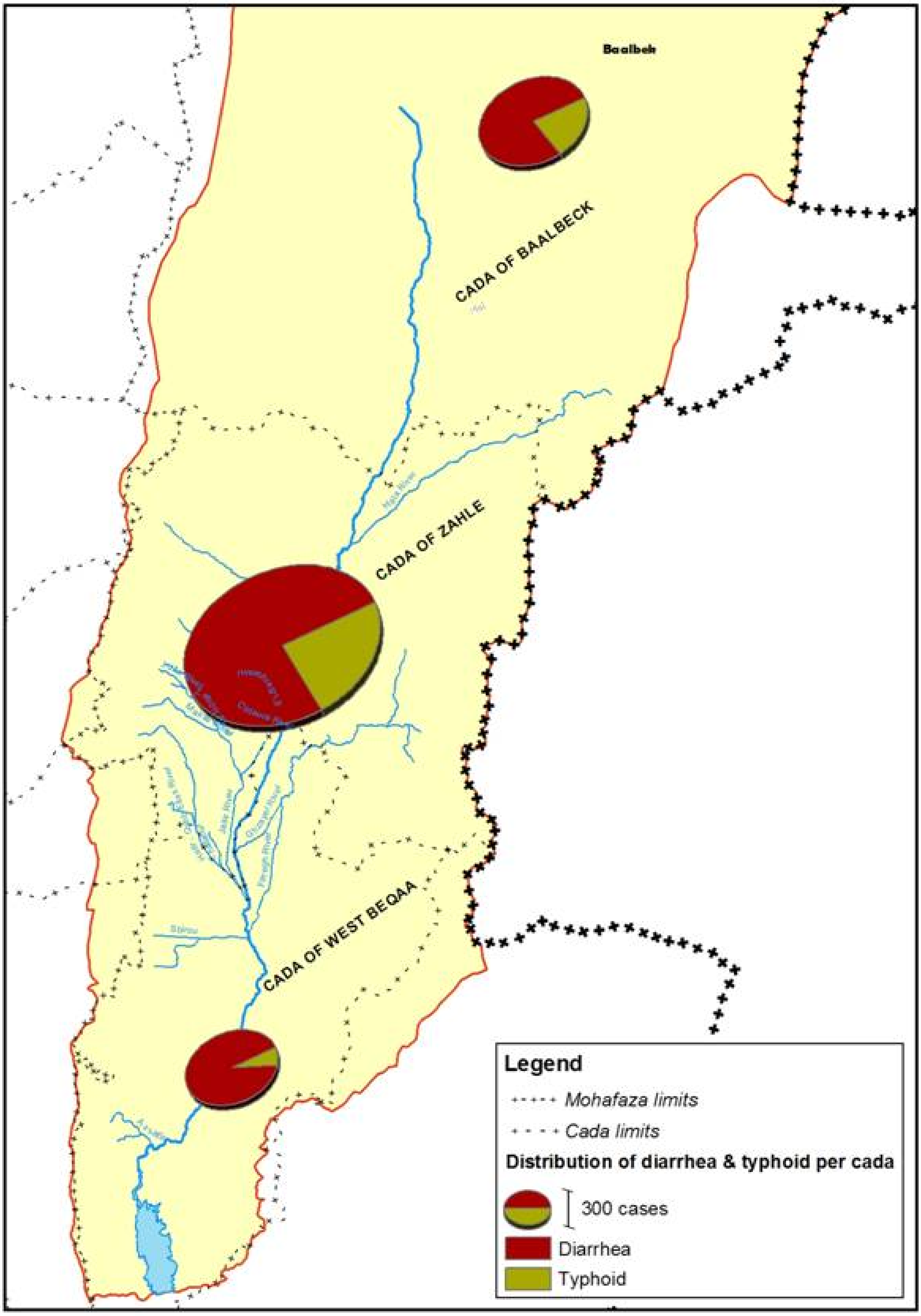


Figure 44. Recorded diarrhea and typhoid cases in surveyed medical facilities.

Evidently, the majority of cases was recorded near large communities and their distribution is consistent with the pattern of greater levels of pollution detected near these communities and which are predominantly associated with the discharge of untreated wastewater in the Litani river. It is equally important to note that the recorded 6,150 cases of diarrhea and typhoid are considered to be a minimum estimate because:

1. Many cases are treated in private clinics; therefore they cannot be captured by the survey of hospitals and dispensaries.
2. Many patients do not visit medical facilities, especially for less severe diarrheas. They simply buy medicaments from pharmacies, without consulting a hospital, a dispensary or a private clinic.
3. Because of institutional constraints, data collection did not take place in two hospitals located in the district of Zahle. A follow up on this issue is needed.

The time and resource constraints did not allow the survey of private clinics and pharmacies to capture a more representative diarrhea and typhoid cases in the basin. Similarly, the survey did not capture children mortality related to water pollution. Equally important but not investigated at this stage due to the same constraints, are averting expenditures which constitute a reflection of the damage associated with water pollution and could be a significant component of the total damage.

The next step is to estimate the economic value on waterborne illnesses. This would entail the assessment of the treatment cost of recorded diarrhea and typhoid cases, the opportunity cost of the time spent being sick as well as the value of discomfort resulting from illnesses (using the Disability Adjusted Life Year or DALY approach). In the case of children mortality, the DALY approach will be used to assess the value of statistical lives losses if data were obtained. Averted expenditures will also be estimated if data were obtained. Evidently, the potential economic damage will be partially captured and is likely to be much lower than the real damage.

It is noteworthy at this point to comment on available information and data in the country because they can be used as an indicator in the event local basin data could not be obtained within the framework of the present project. In this context, several studies have been published at the country level (UNDP, 1995; Jaradeh, 1998; El-Fadel *et al.*, 2003; and World Bank, 2004). In short, similar to worldwide trends, Lebanon suffers from adverse health impacts as a result of water pollution. Data pertaining to water-related mortality and morbidity in the country are limited due to the absence of a proper disease reporting mechanism. Available data are restricted to prevalent known water-related diseases, including diarrhea, typhoid and paratyphoid, and hepatitis A. In terms of mortality, the United Nations Development Program study (UNDP, 1995) reported that in 1990 each child under five is exposed, on average, to 3.5 incidents of diarrhea each year, causing the death of 750 children per year. While more recent data are not available, this value may be an over-estimation, especially that efforts for the improvement of water supply and sanitation have been on going. As for morbidity, the average annual number of reported incidents of dysentery, hepatitis A, and typhoid and paratyphoid for the years 1995 to 2000, as compiled by the Directorate of Preventive Medicine of the Ministry of Health (MoH), were 529, 287, and 809, respectively (Figure 45).

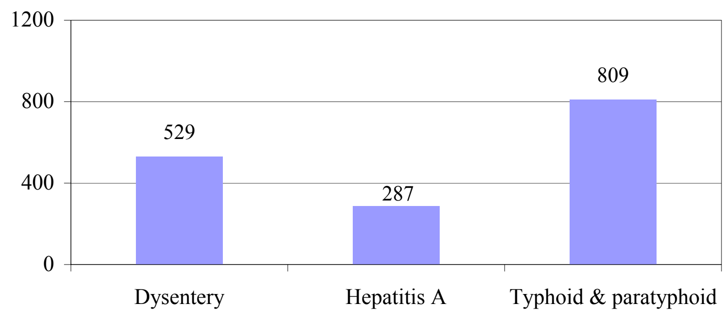


Figure 45. Average number of reported cases per year in Lebanon for the period 1995-2000 (MoH, 2000)

Yet other studies reported that the MoPH found high numbers of water-related morbidity cases in the region between 1995 and 1997 (Table 12), and these numbers are likely under-reported (Jaradeh, 1998; EpiNews, 2005). Such illnesses, while not entirely due to surface water quality, are indicative of water supply problems.

Table 12. Water-related illnesses in the Litani watershed as reported by the MOPH

Disease	*1995[1]*	*1996[1]*	*1997[1]*	*2003[2]*	*2004[2]*
Dysentery	414	990	559	2	9
Hepatitis	135	217	301	60	64
Typhoid	398	524	497	239	249
Bilharzias	2	3	3	0	0

[1]Jaradeh, 1998; [2]EpiNews, 2005

While the above statistics may differ depending on the source of the information, they may be indicative in the absence of basin-specific comprehensive surveys.

6. FARMERS SURVEY

The main objective of the field Farmers Survey was to examine the damage associated with algae proliferation along Canal 900 as a result of the development of eutrophic conditions associated with increased nitrogen and phosphorous levels that are directly linked to wastewater discharge and agricultural practices throughout the basin. This damage will translate into an incremental cost to farmers in terms of equipment damage and potential decrease in the retail value of their produce associated with the negative social perception regarding irrigation with polluted water from Canal 900. Although the water in the basin is equally polluted, Canal 900 is a special case where algae proliferation accentuates the pollution effects and makes them visible and hence creates or increases the social stigma about the water in the Canal. The damage to equipment appears to be limited to drip irrigation systems (extra cost related to the cleaning of the filter and of the network as well as to the replacement of the sand used in the cleaning operation, etc.) According to Litani River Authority, the area irrigated by Canal 900, based on farmers' subscriptions by the end of the year 2004, exceeds 660 Ha. For the purpose of the current farmers field survey, a questionnaire (Appendix J) was developed specifically for the project and administered to farmers who irrigate their land from the Canal 900 water. The survey revealed that the major part of this area is irrigated by sprinklers (Figure 46). The survey covered 16 farmers using a drip irrigation system. The distribution of surveyed farmers in the different villages is shown in Figure 47. The cultivated land of surveyed farmers is about 75 Ha, representing approximately 60 percent of the total irrigated land with a drip irrigation system along Canal 900.

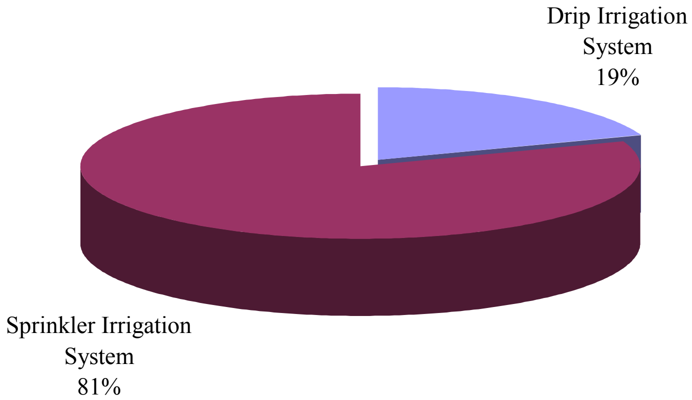


Figure 46. Irrigated land by Canal 900 according to the type of irrigation system

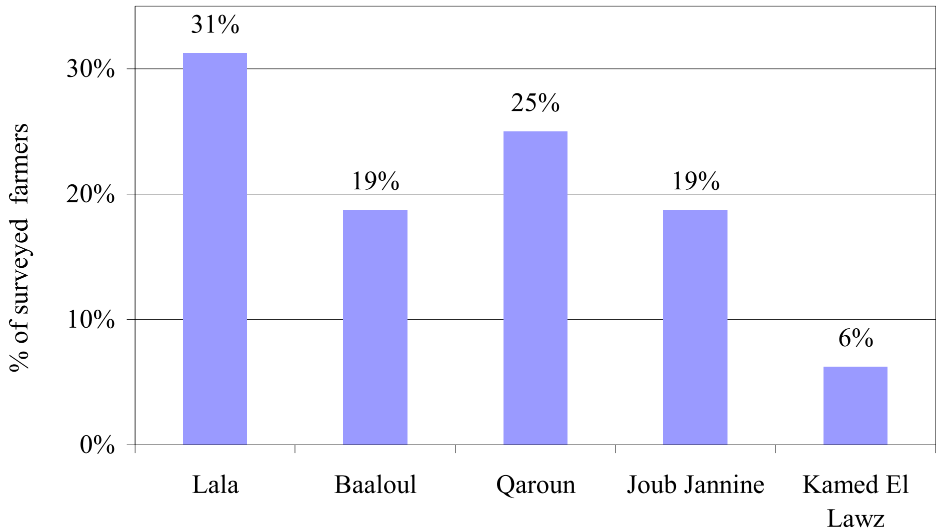


Figure 47. Distribution of surveyed farmers in the different villages

The next step is to estimate the average incremental cost per unit land which will be aggregated to the total irrigated land by a drip irrigation system to reflect the damage cost of algae proliferation in Canal 900. Similar to the Health Surveys, time and resource constraints will limit the damage assessment in terms of estimating losses associated with the potential decrease in the market value of the farmers produce as a result of social perception of polluted water in Canal 900.

7. AGRICULTURAL SURVEY

The upper basin of the Litani River extends over a wide area that occupies more than 17 percent of the Lebanese territories (around 180,000 ha), and constitutes one of the most fertile lands of the country where intensive irrigated agriculture is practiced. Irrigated agriculture is considered as a source of surface water and groundwater non-point source of pollution (NPS) through the leaching of fertilizers and pesticides into streams, lakes and groundwater. The most significant nutrient or fertilizer component affecting water quality is nitrogen (N, as nitrate), as the remaining main fertilizer components (phosphorus and potassium) are bound to calcareous soil, the most represented soil type in Lebanon. As for pesticides, they may also be transported by water, depending on their retention and biodegradation properties.

An Agricultural Survey was conducted in the upper Litani River basin and around 37 farmers were interviewed. The questionnaire addressed several issues including land tenure, cultivation and farm management practices, and agrochemical use. The aim of this survey was to gather, synthesize and analyze information related to the impacts of on-farm practices on water quality management in the upper Litani River Basin and Lake Qaraoun, and to propose recommendations for subsequent program intervention related to the above mentioned issue.

With respect to land tenure, the survey showed that more than 60 percent of the farmers lease land. These farmers tend to use high fertilization practices with intention to maximize benefit. This leads to increased levels of nitrogen in surface and ground water.

The project area includes crops with high demand for agrochemicals (potatoes, summer vegetables…) and crops demanding less agrochemicals (wheat, barley/vetch, vineyards…). The dominant crop, as shown in Figure 48 and Figure 49 below, is wheat which is cultivated by 67 percent of the interviewed farmers and covers more than 950 ha of total surveyed farmed area. Follwed by vegetables covering almost 300 ha and planted by 63 percent of the farmers, then potatoes come third, grown by 54 percent of the farmers over an area of around 250 ha. Other important crops are forage corn, sugar beet, vineyards and fruit trees.

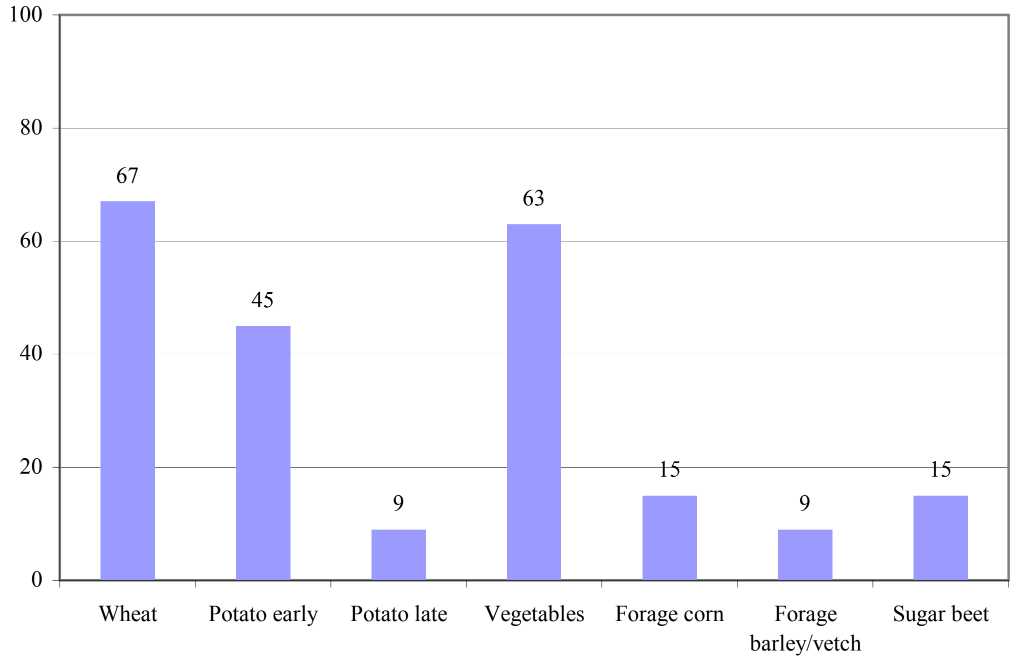


Figure 48. Percent distribution of surveyed farmers by crop type

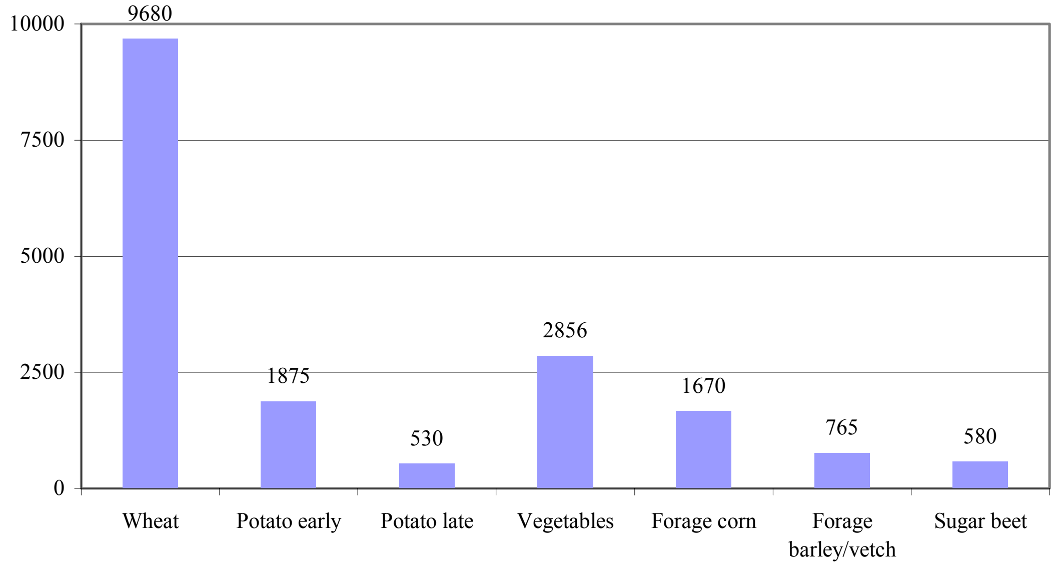


Figure 49. Cultivated area in dunum by crop type for the surveyed farmers

The Survey revealed that surface water is the major source for irrigation, whereby more than 80 percent of the surveyed farmers depend on it either fully or partially. On the other hand, more than 40 percent depend fully or partially on groundwater. Only 25 percent of the surveyed farmers use strictly groundwater for irrigation (Figure 50).

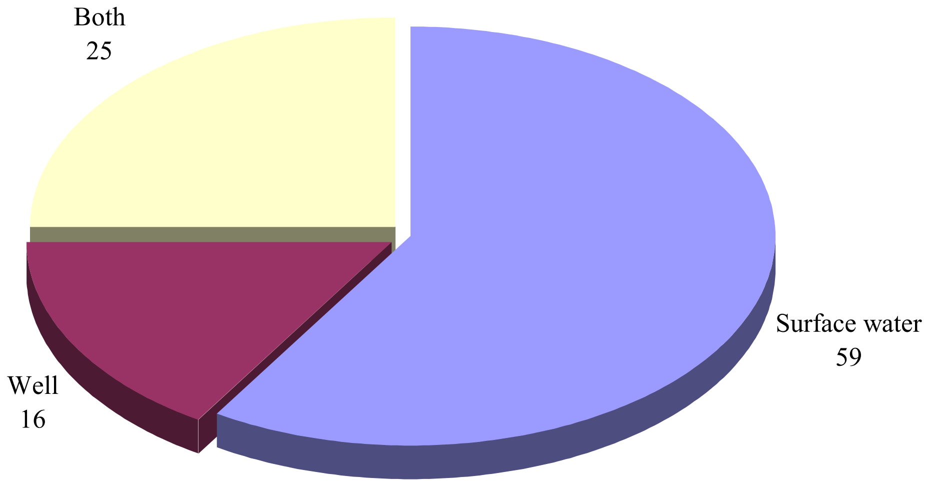


Figure 50. Percent distribution of surveyed farmers by irrigation water source

Sprinkler irrigation is dominant. It is practiced by around 94 percent of the interviewed farmers. Drip irrigation system is used by 22 percent of the surveyed farmers, especially on vegetables. Raingun systems (12 percent) are newly introduced and are gaining more territory after the introduction of the forage corn to the Beqaa. Furrow is still practiced by 19 percent of the farmers (Figure 51). Flood irrigation is not used by any of the surveyed farmers, due mainly to water scarcity in the region. The type of irrigation systems adopted defines the water use efficiency in the area and highlights the risk of agrochemical leaching to groundwater. For instance, furrow is the least water efficient and drives more agrochemicals to the groundwater aquifers as compared to the other systems, especially the drip irrigation systems. It is important to note that irrigation water is not the only vector for agrochemical seepage to the groundwater, rain and especially heavy showers are major contributors to this process.

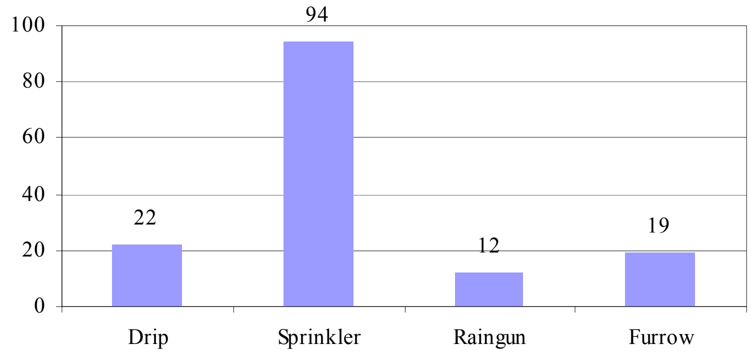


Figure 51. Percent distribution of irrigation systems adopted by surveyed farmers

The farmers listed several problems related to their agricultural practices and farm management. The most recurrent problems mentioned by 75 percent of the surveyed farmers are the high cost of production, and the low market prices due to foreign competition. The high cost of production might also be due to high cost of entrants and labor, and farm mismanagement. Another problem, pest control, was mentioned by 27 percent of the surveyed farmers. Other problems were pointed out including drainage, fertility and polluted water (Figure 52). Not all issues might be well perceived by farmers. For instance, farmers do not often see that over-fertilization might be a significant contributor to the high cost of production. Nevertheless, any program that plans to improve water quality by improving agricultural practices has to take these problems into consideration to gain farmer cooperation.

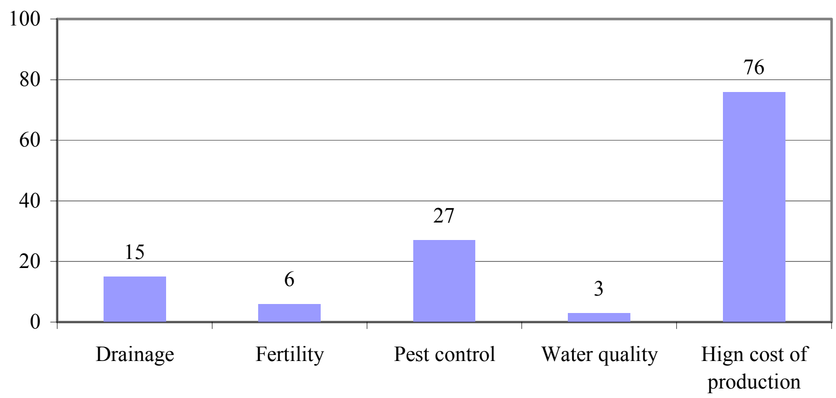


Figure 52. Percent of farmers suffering from cultivation-related problems

The main agrochemicals affecting water quality are pesticides and fertilizers, as previously mentioned. Thus, the winter technical survey targeted these agrochemicals, among other parameters to determine their levels in water. Yet, the winter technical survey revealed no sign or insignificant levels of pesticides in both surface and groundwater due to several reasons listed in Section 3.2. Therefore, the data acquired from the agricultural survey regarding pesticide application will be analyzed following the summer technical survey, in case high pesticide levels were detected. In relation to fertilizers, the winter technical survey revealed nitrogen levels exceeding the drinking water guidelines in many of the sampled groundwater wells. While these levels may pose a health risk if the water is used for drinking, such nitrogen levels are acceptable for irrigation, as nitrogen can be used in fertigation. The levels of the other major fertilizer component, Phosphorous, were acceptable, mainly due to the fact that it is bound to soil and does not leach to groundwater. As such, the analysis of the results of the agrochemical practices collected as part of the agricultural survey focused on nitrogen fertilization. In this context, nitrogen fertilization practices were studied for the main crops (wheat, vegetables and potatoes) and revealed the following:

- There is no practical nitrogen over-fertilization of wheat. The amounts which are applied are usually below recommended rate for the wheat yield in the basin.
- Around 28 percent of surveyed farmers cultivating vegetables are over-fertilizing with nitrogen.
- More than 88 percent of the farmers growing potatoes do over fertilize their lands. The survey showed that more that 36 percent of the farmers fertilize with an amount that is twice or more than the needed nitrogen amount for potatoes.

It is worth noting that nitrogen leaching is not only due to over-fertilization but is also a matter of application timing. For instance, nitrogen fertilization of winter crops during the rainy season increases the likelihood of nitrogen leaching into groundwater.

In light of the Agricultural Survey results, an agricultural program is needed to alleviate the water pollution problem in the upper Litani basin originating from agricultural practices, while taking into consideration the production problems faced by the farmers to ensure farmer buy-in and cooperation. Many methods are typically used by governments to promote new and environmentally sound agricultural practices; however, extension programs continue to rank high. Recognizing the drawbacks and needs of this sector in the region, and in light of the successes of worldwide agriculture extension programs, it seems that the initiation of a technology transfer extension program will constitute the cornerstone of a sustainable agricultural development in the upper Litani basin: economically by increasing the benefit margin of farmers (to respond to the major perceived problem by farmers), and environmentally by using adequate proportion of agrochemicals that reduces their environmental impacts.

A series of questions in the agricultural survey targeted the extension needs of farmers and showed that more than 58 percent of the surveyed farmers are actually receiving extension from three sources, agrochemical suppliers (80 percent), the Ministry of Agriculture, and farmer cooperatives in the area (Figure 53).

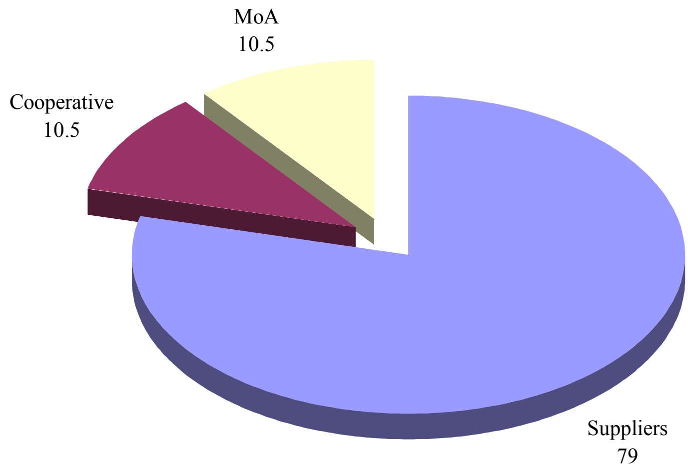


Figure 53. Extension sources for farmers receiving extension (%)

Yet, the majority of farmers (82 percent) stated that they need extension, and indicated very clearly (81 percent) that they foresee the Ministry of Agriculture as the preferred reliable source. Some other farmers mentioned universities and cooperatives as a preferred source of extension, and only 4 percent listed agrochemical suppliers as a source for agricultural extension (Figure 54).

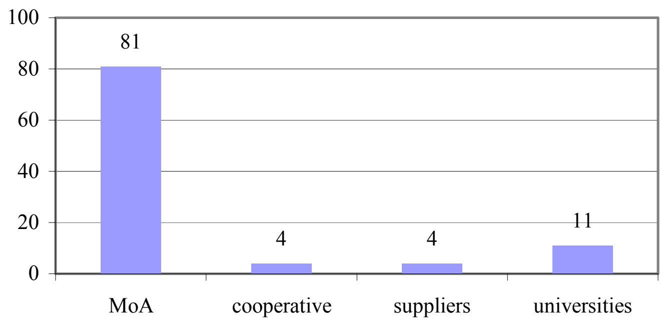


Figure 54. Preferred source of extension (%)

8. LEGAL AND INSTITUTIONAL ANALYSIS

Once the investment options for the four main sector-polluters are defined, a ranking and prioritization of those options will be carried out to arrive at the best management scenarios. Ranking will take place according to well-defined criteria that will be formulated on two additional different levels besides the purely technical and quantitative aspects, namely, legal, and institutional.

8.1 Legal Analysis

Every option identified in all four sectors will be analyzed according to the following two main questions:

- Is it possible to carry out the option within the present regulatory and legal context?

- Does implementation of the option require the amendment of an existing regulation or law or even the issuance of an entirely new regulation or law?

8.2 Institutional Analysis

The institutional analysis will be somewhat different for each one of the four sectors-polluters although there will still be similarities in the approach. In this context, a set of evaluation criteria will be developed and used for each sector. For instance, the analysis will start, in every sector, with the identification of the institution(s) directly concerned with the implementation of the option. Thereafter, an evaluation of every option according to well-defined indicators will be carried out. Example indicators include:

- Existence and extent of overlap (if any) among institutions directly concerned with the implementation of the option when there is more than one institution.
- Extent to which the institution is operational
  - degree of operational independence
  - whether internal regulations are fully existing and enforced or still being prepared and updated.
  - whether the institution needs restructuring and re-organization
- Number and level of skill of existing personnel
- Financial resources and constraints with degree of independence in preparing the budget.

In addition, every sector will have specific additional institutional criteria such as:

8.2.1 Domestic Wastewater

When analyzing domestic wastewater options, wastewater treatment plans will be evaluated from an institutional perspective. Specific parameters used would include:

- Technical and administrative ability to operate and maintain a treatment plant.
- Previous experience in operating another public service.
- Right and ability to charge and collect fees for the services provided.
- Existence of a suitable and operational sewer system
- Potential for a public/private partnership

8.2.2 Solid Waste

When analyzing solid waste management options, plans will be evaluated from an institutional standpoint. Specific parameters used would include:

- Technical and administrative ability to operate and maintain a system.
- Previous experience in operating another public service.
- Right and ability to charge and collect fees for the services provided.
- Potential for a public/private partnership

8.2.3 Agriculture

When analyzing agricultural options, institutional evaluation of feasible control mechanisms for the improvement of agrochemicals usage will be emphasized. Specific parameters used would include:

- Public extension services
- Public funding

  - grants
  - access to soft loans
- Enforcement mechanisms (who does what and how)
- Previous experience

8.2.4 Industry

When analyzing options for industrial wastewater, institutionally feasible mechanisms for the reduction of industrial discharges and compliance with existing standards will be emphasized. Specific parameters used would include:

- Public funding
  - grants
  - access to soft loans
- Public provision of extension services
  - Environmental audits
  - Cleaner production
  - Pollution prevention
- Enforcement mechanisms (who does what and how)
  - With grace periods
  - Without grace periods
- Voluntary compliance
- Previous experience especially with various enforcement mechanisms

9. COLLABORATIVE EFFORTS

The National Working Group (NWG) is the link between the project and the stakeholders community. According to the original project document, 'the working group will actively participate in and monitor the implementation of all project activities related to their respective themes'.

Following the recommendations of the Rapid Review and the feedback from the first BAMAS workshop, parties to be represented in the BAMAS National Working Group (NWG) were selected. The criteria for selecting the representatives of these parties included 1) expression of willingness to participate in the First Workshop Recommendations Form, and 2) enthusiasm for the project objectives and expression of willingness during one-on-one meetings with the project team. A roster list was prepared, the candidates were contacted and meetings and/or teleconferences were held. Special efforts were exercised to encourage the participation of the municipality of Bednayel, which is very active in water related issues. However, this has not materialized. A total of 17 members were invited, representing the major stakeholders in the project, namely: government, municipalities, professional associations, farmers, NGOs and academics (Table 13).

Table 13. Members of the BAMAS National Working Group

Party	*Name*	*Party*	*Name*
Litani River Authority	Hussein Rammal	*Municipality of Zahleh*	Ibrahim Abou Dib
Council for Development and Reconstruction	Zuheir El Hassan	*Municipality of Taanayel*	Assaf Sawaya
Ministry of Environment	Assaad Saadeh	*Chamber of Commerce*	Said Jedeon
Ministry of Energy and Water	Hassan Jaafar	*Industrialists Association*	Muhieddine Nakhlawi
Ministry of Agriculture	Hussen Nassrallah	*Sugar beet Industry*	Antoine Nohra
Ministry of Industry	Rabih Saab	*Farmer*	Safa Issa
Bekaa Water Establishment	Mohamed Shoubassy	*Environmental Club of West Bekaa*	Omar Kanaan
The Federation of the Municipalities of the Bekaa	George Khoury	*Academician*	Selim Makssoud
The Federation of the Municipalities of the Qaraoun	Rabih Joumaa		

The NWG is expected to play a vital role in the BAMAS project in:
- Following up on project activities
- Contributing to the development of options for water quality management in the Upper Litani Basin
- Communicating with stakeholders to update them on project achievements and to relay their interests and concerns
- Endorsing and following up on the implementation of the BAMAS Action Plan

The BAMAS project organized its first meeting for the NWG on Wednesday April 20, 2005 at Chtaura Park Hotel, Chtaura, Bekaa. The main objective of this meeting was the formation of the BAMAS NWG and the launching of its activities and contributions to the project. The agenda of the meeting is included in Appendix J.

9.1 Attendance and presentations

All members of the NWG attended the meeting, except for the Municipality of Bednayel which did not accept to participate for political reasons. Other attendees included representatives from USAID and key team members on the BAMAS project (Figure 55).

Figure 55. BAMAS First NWG Meeting

The meeting kicked off with welcome addresses by the Project Manager, Mr. Mark Saadeh and the LRA representative, Dr. Hussein Rammal. Mr. Mark Saadeh followed with a concise presentation of the project, focusing on its structure, objectives and progress to date. Dr. Mutasem El Fadel then briefed the members of the NWG on the activities undergone as part of the *Technical Survey* and the results obtained regarding surface and groundwater quality, using illustrative maps. Mr. Jean Karam followed, highlighting the importance of the institutional and legal aspects in the development and implementation of water quality management options with emphasis on the role of stakeholders, particularly the NWG. The technical presentations elicited a great deal of questions by the participants. Clarifications were offered by the BAMAS team. The participants also requested the Rapid Review Report and other project documents to be able to follow up closely on Project activities.

9.2 Discussions

Following the update on project achievements, Dr. Ramy Zurayk presented the document defining the role and responsibilities of the NWG and its mechanism of action (Appendix M). This session involved an active discussion in which all members participated. There were inquiries about specific issues, and some modifications were suggested. On the whole, there was a general consent on the contents of the document, with minor editorial changes.

In the last session of the meeting the contribution of the NWG in the coming BAMAS Workshop 2 was discussed. It was agreed that the members of the NWG will prepare a presentation on the project, highlighting their roles and responsibilities. They will also be formally introduced to the workshop attendees. Four of the members (Mr. Rabih Saab from the Ministry of Industry, Mr. Ibrahim Abou Deeb from the Municipality of Zahleh, Mr. Said Jedeon from the Chamber of Commerce, Industry, and Agriculture in Zahleh and Mr. Omar Kanaan from the Environment Club of the West Bekaa) volunteered to work together on preparing the NWG intervention, which will be reviewed and discussed by all members during the second NWG meeting.

Before closing the meeting, it was decided that the second NWG meeting will be held on the afternoon of Wednesday May 24th in the Bekaa.

10. BAMAS SECOND WORKSHOP

The 2nd workshop was held on June 1, 2005 at the Chtaura Park Hotel, in Chtaura. It was attended by 70 participants (out of 100 invitees). The participants represented institutions and organizations from the government and the civil society including the following (Figure 56):

- Litani River Authority,
- USAID,
- Project's National Working Group,
- Ministry of Agriculture,
- Ministry of Energy and Water,
- Ministry of Environment,
- Ministry of Industry,
- Bekaa Water Establishment,
- Zahleh and Chamssine Water Authority,
- Directorate General of Urban Planning,
- Concerned, Municipalities: Chtaura, Majdel Anjar, Mansoura, Qaa El Rim, Qabb Elias, Riyak and Haouch Hala, Taanayel, Zahleh-El Maal'a,
- Federation of the Municipalities of the Sahel,

- New deputy of the Bekaa Mohafaza,
- National Center for Remote Sensing,
- Chamber of Commerce, Industry, and Agriculture,
- Lebanese Industrialists Association,
- Farmers,
- Academia, Universities: AUB, USJ-ESIAM, Lebanese University- Faculty of Sciences,
- Consulting firms and projects being developed partially or fully in the Litani basin: CDM/ Dar Al Handassah, OPTIMUM, IRWA, LWPP,
- Environmental Club of West Bekaa,
- Friends of Ibrahim Abd El Aal.

Figure 56. BAMAS Second Workshop

The Workshop aimed at presenting and discussing the findings of the Winter Technical Survey and at introducing the National Working Group.

After opening addresses by each of: LWQM project manager, Mr. Mark Saadeh, USAID representative, Ms. Sana Saliba, and LRA Director General, Mr. Ali Abboud, the meeting proceeded with a cursory presentation of the results of the extensive survey that was implemented during the past few months, including the surface and groundwater quality sampling results and recommendations presented by Dr. Mutasem El Fadel and Dr. Adel Abou Jaoudeh, agricultural & health survey results presented by Mr. Dany Lichaa and Dr. Mutasem El Fadel, the review of planned wastewater treatment plants and operation and maintenance issues presented by Dr. Adel Abou Jaoudeh and Mr. Roger Melki, as well as the findings of the Canal 900 algae control testing via the use of copper sulfate presented by Dr. Mohamed Chebaane (Appendix N). This was followed with an active plenary questions/answers session that reflected the hightened interest among the attendants in the presented results of *Technical Survey*. The second part of the workshop started with a presentation by Mr. Mark Saadeh on long-term water quality monitoring in the Upper Litani River Basin followed by a presentation by Mr. Omar Kanaan, a member of the National Working Group on the roles and responsibilities of this group, which was formed in the wake of the first workshop as an advisory committee representing the main stakeholders from the public as well as the private sector, including the local community groups. The last two interventions by Dr. Mohamed Chebaane and Mr. Jean Karam focused on the recommended investments options and implementation support tools including capacity building, institutional strengthening, legal reforms, public education, and awareness, and sustainbility of the the National Working Group.

The meeting ended with a second plenary session in which views surrounding the recommendation of the investment options and future project interventions were exchanged.

In his closing address, Mr. Ali Abboud underscored the unique spirit of cooperation and collaboration between all stakeholders in this workshop as well as throughout the project's implementation.

11. CONCLUSIONS AND RECOMMENDATIONS

The *Technical Survey* detailed in this report included field reconnaissance, environmental sampling and analysis campaign (surface and groundwater, sediments, soil, and fish), and the health, farmers, and agricultural surveys. The methods for legal and institutional analysis of investment options were defined and collaborative-participatory planning efforts to date were documented. The main conclusions are outlined below:

- Several chemical and biological indicators exhibited concentrations exceeding drinking, bathing, domestic, and irrigation water quality standards even at the peak water flows of the wet season when the dilution effect is highest. Evidently, the contamination levels will only increase during the dry summer season.

- Field observations and water quality analysis indicate that the most significant sources of contamination to surface and groundwater are associated with the uncontrolled discharge of untreated wastewater along the Litani river and its tributaries highlighting the need for investing in wastewater treatment plants.

- The highest levels of contamination along the river fall within the mid-upper Litani basin where the largest communities are located and are discharging into the river.

- The quality of the water in Qaraoun Lake and in Canal 900 was found to be acceptable for irrigation under certain restrictions.

- The high levels of nitrates in groundwater samples ascertained the impact of current agricultural practices on groundwater quality and the importance of extension programs to insure proper application of fertilizers in the dry season.

- Soil, sediment and fish samples exhibited low to high levels of heavy metals. Additional analysis is needed to assess the implications of these levels.

- The wet season results are certainly not reflective of the worst case conditions in the basin. The planned dry season campaign will provide a more comprehensive understanding of the level of environmental stresses and hence will further assist in defining investment options to enhance environmental management towards the improvement of water quality in the basin.

- The WWTPs survey revealed that while the CDR-MEW master plan and the proposed WWTPs through the USAID funded program target wastewater management in villages geographically distributed throughout the upper Litani basin, a significant number of small villages, representing around 13% of total population, is still not served within their schemes.

- The health survey revealed that recorded cases of 6,150 waterborne illnesses during the year 2004 are considered to be a minimum estimate. The majority of these cases was recorded near large communities and their distribution is consistent with the pattern of greater levels of pollution detected near these communities and which are predominantly associated with the discharge of untreated wastewater in the Litani river. The time and resource constraints did not allow the survey of private clinics and pharmacies to capture a more representative diarrhea and typhoid cases in the basin. Similarly, the survey did not capture children mortality related to water pollution. Equally important but not investigated at this stage due to the same constraints, are averting expenditures which constitute a reflection of the damage associated with water pollution and could be a significant component of the total damage.

- The farmers' survey revealed that the damage to equipment as a result of algae proliferation appears to be limited to drip irrigation systems and main filter intakes (extra cost related to the cleaning of the filter and of the network as well as to the replacement of the sand used in the cleaning operation, etc.). The time and resource constraints will limit the damage assessment in terms of estimating losses associated with the potential decrease in the market value of the farmers produce as a result of social perception of polluted water in Canal 900, as well as the loss to the LRA in terms of freezing any available funding for Canal 900 expansion.

- The agricultural survey revealed that agrochemical usage and application rates are generally not appropriate. As such, an agricultural extension program is needed to alleviate the water pollution problem in the upper Litani basin originating from agricultural practices, while taking into consideration the production problems faced by the farmers to ensure farmer buy-in and cooperation.

- The collaborative-participatory planning efforts resulted in the formation of a National Working Group that is following up on project activities with the project team and Contributing to the development of options for water quality management in the Upper Litani Basin.

Based on the results of the *Technical Survey,* the 2nd National working group meeting, and the 2nd project workshop, the upper Litani Basin stakeholders endorsed the following six water quality management/pollution remediation investment options:

- Coverage of gaps in domestic wastewater management;
- Strengthening capacities in operation and maintenance of WWTPs;
- Integrated efficient water use-fertigation/pesticide management- crop production agricultural extension programs;
- Long-term water (SW-GW) quality monitoring program;
- Strengthening capacities in Industrial Wastewater Management & Environmental Compliance: regulatory, incentive based, and voluntary compliances;
- Strengthening capacities in Solid Waste Management.

It was also recommended to consider the subsequent key support tools for the design and implementation of above options:

- Stakeholder participation including Public and private institutions, civil society (NGOs, other associations, gender);
- Public Awareness;
- Training and capacity building;
- Institutional strengthening;
- Legal support.

The following activities are planned for the remaining project period:

- Work with NWG on identification of institutional responsibility for each of the above recommended six water quality management/pollution remediation options;
- formulate and cost of each option;
- Continue implementation of the algae program including training of LRA staff;
- Conduct summer sampling survey;
- Complete DSS for prioritization of domestic wastewater management options;
- Complete groundwater modeling to identify groundwater vulnerability areas, essential for groundwater quality monitoring and management;
- Start preparation of Action Plan;
- Convene three NWG meetings and two workshops

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LIST OF APPENDICES

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Appendix A- Log sheets forms

Appendix A1. Reconnaissance log sheet for surface water samples

No.	*Sample Matrix*	*Field validated sample location description*				
		Code	*Photo ID*	*E (DD)* *N (DD)*	*Alt. (m)*	*Description/Remarks*
1				E N		
2				E N		
3				E N		
4				E N		
5				E N		
6				E N		
7				E N		
8				E N		
9				E N		

Appendix A2. Reconnaissance log sheet for groundwater samples

WELL DESCRIPTION FORM

Engineer name: ________________ **Date:** _______________ **Time:** ____________

Well Code: ________________ **Well Depth:** ________ **m** **Geologic Formation Tapped:** ____________________________

Well Location:

Name of Site	Town/City	District/Caza	Region/Mohafaza

GPS Coordinates:

N	
E	

Relative Position of Well:

Perpendicular Distance from Sea Coast	Elevation Above Sea Level (GPS)

Well Owners:

Public Sector	Name of Public Sector	Private Sector	Name of Private Sector

History of Well:

Date of Construction	Duration of Construction	Is Borehole Plumb?	Is Borehole Straight?

Type of Usage:

Human Consumption	Industrial Purposes	Agricultural Purposes	Monitoring Purposes

Pumping Rate and Well Yield:

Pumping Rate	Well Yield

Casing:

Casing Length	Casing Depth	Casing Material

Casing Diameter:

6”	8”	10”	12”	14”	16”	20”	24”	

Screen:

Screen Length	Screen Depth	Screen Material

Screen Diameter:

4”	6”	8”	10”	12”	14”	16”	17”	18”	21”	23”

Screen Properties:

Screen Type	Slot Size	% Open Area

Filter Pack:

Filter Pack Used	Filter Pack Depth	Gravel Pack Used	Gravel Pack Depth

Pump Size:

4”	5”	6”	8”	10”	12”	14”	16”	20”

Appendix A3. Surface sample log sheet

1. **Sample code:** ____________________

2. **Sampling station:** N ____________________ E ____________________ Altitude __________m

3. **Date:** __________ 4. **Time:** ____________

5. **Weather conditions:** ☐ Sunny ☐ Cloudy ☐ Windy ☐ Rainy

6. **Photo IDs:** ____

7. **Site description:**
____
____
____

8. **Samples collected:** ☐ Standard chemistry ☐ Heavy metals ☐ Microbiology ☐ Pesticide

9. **Sample depth from surface:** ____________ **m**

10. **Problems encountered/ adaptations made during sampling:** ____________________
____
____

11. **Analysis undertaken on-site:**

Variable	**Method used**	**Equipment name**	**Reading Value**
Temperature	____________	____________	____________°C
pH	____________	____________	____________
DO	____________	____________	____________

12. **General remarks:** ____
____
____

13. **Collector:**	Name ____________	Signature ____________	Date ____________
14. **Data received by:**	Name ____________	Signature ____________	Date ____________

Appendix A4. Groundwater sample log sheet

1. Sample code: ____________________

2. Sampling station: N ________________ E ______________ Altitude _________m

3. Date: ________ **4. Time:** __________

5. Weather conditions: ☐ Sunny ☐ Cloudy ☐ Windy ☐ Rainy

6. Photo IDs: ____

7. Site description: ____

____

____

8. Samples collected: ☐ Standard chemistry ☐ Heavy metals ☐ Microbiology ☐ Pesticides

9. Depth to water table: ____________ **m**

10. Problems encountered/ adaptations made during sampling: ____________________

____

____

11. Analysis undertaken on-site:

Variable	**Method used**	**Equipment name**	**Reading Value**
Temperature	______________	______________	______________°C
pH	______________	______________	______________
DO	______________	______________	______________

12. General remarks: ____

____

____

	Name	Signature	Date
. **Collector:**	______________	__________	__________
. **Data received by:**	______________	__________	__________

Appendix A5. Daily sample log sheet for Environmental Engineering Research Center

Date: _________________

Samples presented by: __________________ **____________ Signature**

Samples received at lab by:_________________ **____________ Signature** **________ Time**

Total number of samples: ________________

Sample ID	*Matrix*	*No. of vials*	*Parameters to be Tested*		
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform		

Appendix A6. Daily sample log sheet for Environment Core Laboratory

Date: ________________

Samples presented by: __________________ ____________ **Signature**

Samples received at lab by:________________ ____________ **Signature** _________ **Time**

Total number of samples: ________________

Sample ID	*Matrix*	*No. of vials*	*Parameters to be Tested*			
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrates ☐ Phosphates
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate

Appendix B. Physical characteristics of the upper Litani basin

B1. Litani river and its tributaries

The first water flow into the Litani river is diverted from the Yammouneh irrigation canal[8] in Saaide area at the northern extremes of the upper Litani basin (Figure 57). This water was supposed to be diverted into a concrete-lined irrigation canal that serves the agricultural lands of Haouch Barada and surrounding areas. However, due to the damaged and non-maintained sections of this canal, the water is diverted intermittently into the Litani river.

Figure 57. Water diversion from Yammouneh irrigation canal

After receiving the water from the Yammouneh canal, the Litani river flows in a southeastern direction through the agricultural areas of Hadath Baalbeck, Hizzine, Haouch Snaid, Bayt Chama, Haouch Er Rafqa, and Tamnine El Tahta before crossing Ablah-Riyak highway (Figure 58). Although the area adjacent to this stretch of the river is characterized by its agricultural nature, scattered residential areas can be equally observed towards Tamnine El Tahta. Moreover, dairy facilities are present such as the milk processing facility in Hadath Baalbeck and the Liban Lait dairy product facility in Haouch Enabi (Figure 59).

Figure 58. Litani river crossing Ablah-Riyak highway

[8] The Yammouneh Irrigation Canal is part of a major irrigation scheme in the Deir El Ahmar area that collects water from several springs in the Yammouneh village which used to feed the former Yammouneh Lake.

(a) Milk processing facility (Hadath Baalbeck)

(b) Liban Lait facility (Haouch Enabi)

Figure 59. Dairy facilities adjacent to Litani river

After crossing Ablah-Riyak main road, the Litani river continues across the agricultural lands of Ablah and Riyak areas, passing adjacent to Tanmiya chicken slaughterhouse and processing facility in Ablah (Figure 60), before joining Hala river on the outskirts of Riyak (Figure 61). Hala river that flows from the Serghaya area in Syria, crosses the borders in Wadi Yahfoufa and continues across Jenta, Massa, and Ali el Nahri areas, before joining the Litani in Riyak.

Figure 60. Tanmiya chicken facility in Ablah area

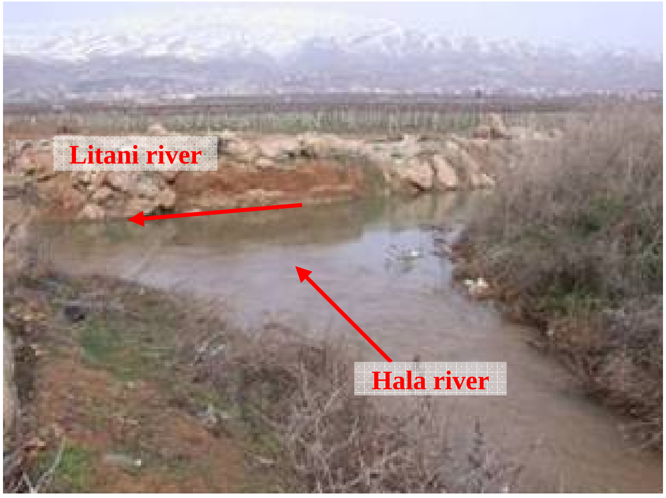

Figure 61. Hala river joining Litani in Riyak area

The combined flow of the Litani and Hala rivers continues in a southeastern direction until it joins with the combined flow of the Berdaouni and Chtaura rivers in El Marj area (Figure 62). Along this section, the Litani river crosses the agricultural lands of Riyak, Delhamiyeh, Bar Elias, and El Marj, and passes in the immediate vicinity of Zahle solid waste landfill (Figure 63). Chtaura and Berdaouni rivers flow from Chtaura and Qaa El Reem springs, respectively (Figure 64). While Chtaura river passes through Chtaura and Taanayel areas, and Berdaouni river passes through Zahle, Saadnayel, and Bar Elias areas, they both meet in El Marj (Figure 65) to form one tributary that ultimately joins with Litani river in the nearby area.

Figure 62. Berdaouni-Chtaura combined flow joining the Litani in El Marj area

Figure 63. Litani river passing adjacent to Zahle solid waste landfill

Chtaura spring

Qaa el Reem spring

Figure 64. Chtaura and Qaa el Reem springs

Figure 65. Berdaouni and Chtaura rivers join in El Marj area

After joining Chtaura-Berdaouni rivers, the Litani river, continues across the agricultural lands of El Marj, and Haouch el Harimeh where it joins the Ghzayel river (Figure 66). Then, it continues on the outskirts of Haouch el Harimeh area before joining the combined flow of Hafir (Qabb Elias) and Jair rivers in the Aamiq area (Figure 67). After that, it flows through the outer reaches of Mansourah, Ghazeh, Tall Znoub, Joub Jannine, Lala, Baaloul, and Saghbine areas, before ultimately discharging in the Qaraoun Lake.

Figure 66. Ghzayel river joining with Litani river in Haouch el Harimeh area

Figure 67. Hafir-Jair combined flow joining with Litani river in Aamiq area

The Ghzayel river, Litani's largest tributary, flows from the Aanjar and Chamsine springs in the Aanjar area (Figure 68). Within a short distance from their source, the water from the two springs meet to form the Chamsine river that again joins the Faour river (that flows from Ras el Ain spring in the Faour area) in an area known as El Ghzayel. After that, the Ghzayel river continues across the agricultural lands in the Bekaa plateau before connecting to the Litani river in Haouch el Harimeh area. On the other hand, Hafir (Qabb Elias) and Jair rivers, flow from Qabb Elias and Jdita springs, respectively (Figure 69). The two rivers meet in the Aamiq area before connecting to the Litani.

Aanjar spring Chamsine spring

Figure 68. Aanjar and Chamsine springs in Aanjar area

Qabb Elias spring Jdita spring

Figure 69. Qabb Elias and jdita springs

In addition to the major tributaries mentioned earlier, several winter water courses and drainage canals were also observed, namely, Makseh river in Mraijat and Maksek areas (discharges in Jair river); Jalala river in Taalabay area (discharges in Chtaura river); Ech Chataoui canal in Tell el Akhdar area (discharges in Hafir river); and Khandaq Sbirou in Aamiq area (discharges directly in Litani river) among others (Figure 70). Drainage canals were observed to be the common system used for draining agricultural flat areas, where excess rainfall is collected through cross drainage channels that connect to lateral collecting canals (Figure 71) which ultimately discharge directly into the Litani river or one of its tributaries.

Makseh river
Jalala river
Ech Chataoui canal
Khandaq Sbirou

Figure 70. Winter water courses and drainage canals in the upper Litani basin

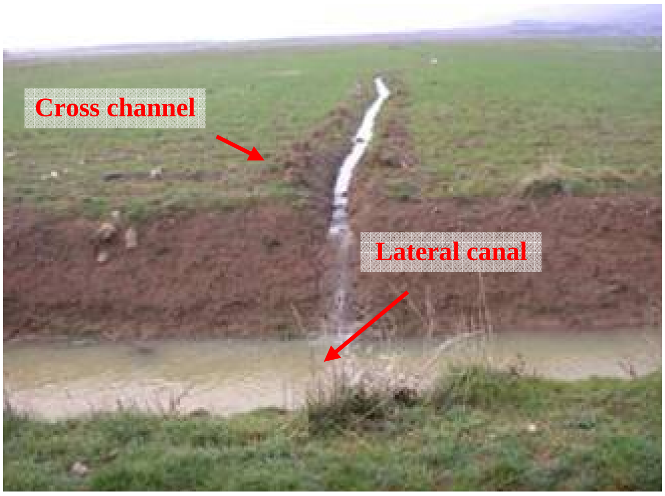

Figure 71. Cross/lateral drainage channels/canals used for draining agricultural flat areas

B2. Canal 900 and irrigation schemes

Canal 900 withdraws water from the Qaraoun Lake for a 1,750-hectare irrigation scheme in the southern part of the Bekaa Valley. The Canal was rehabilitated in 2001 by refurbishing of 14 kms and the construction of an additional 4 kms. It extends from the Qaraoun Dam to a closed end near the village of Kamed El Louz (Figure 72).

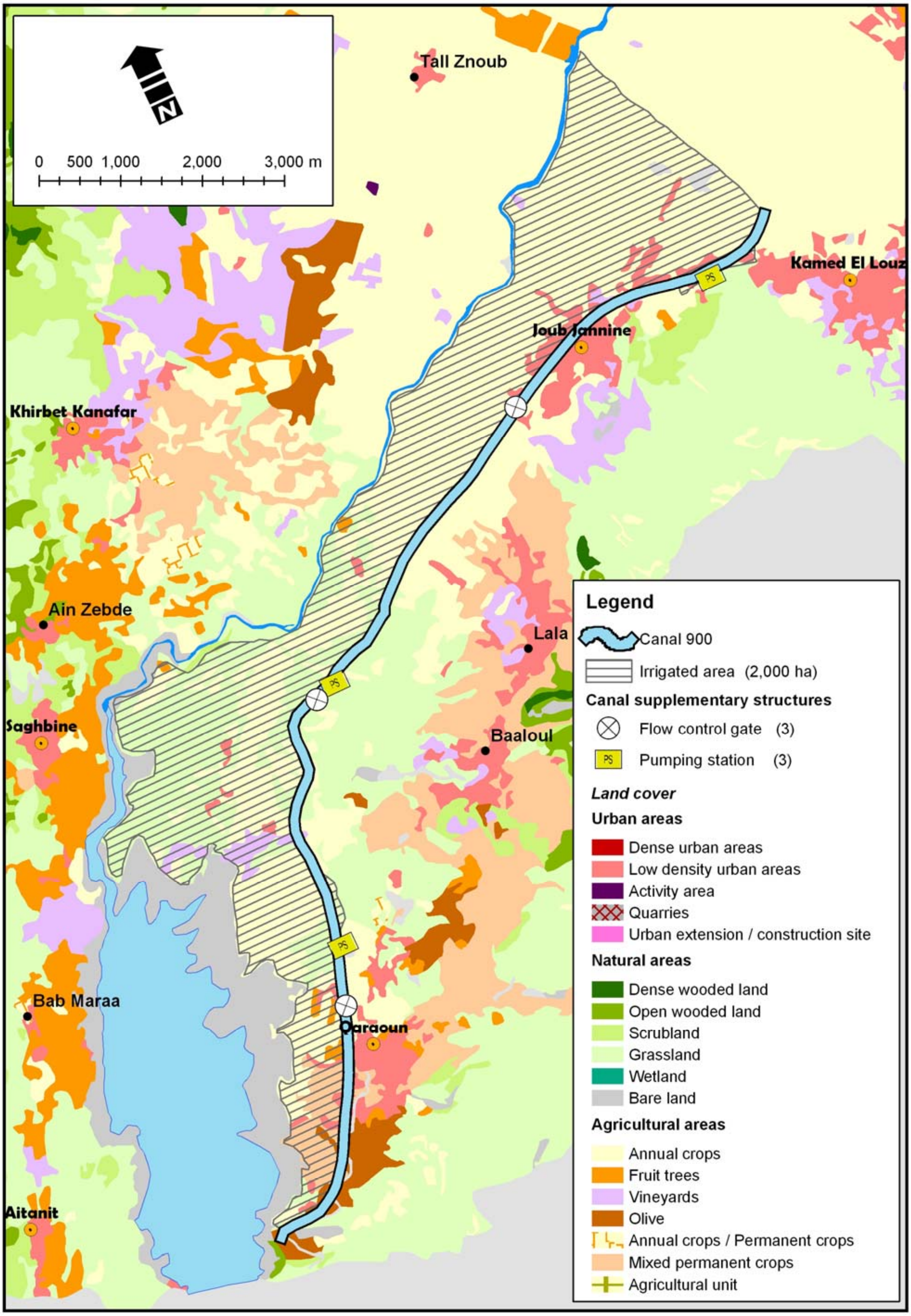

Figure 72. Canal 900 layout with corresponding supplementary structures and land use in the area

Three main areas are currently serviced by the Canal (Qaraoun, Lala, and Joub Jannine-Kamed El Laouz), whereby pumping stations move water from the Canal into regulating reservoirs which then distribute water by gravity in pressured distribution networks that supply water on demand.

B3. Geology and hydrogeology of the Upper Litani Basin

The upper Litani basin valley is constituted by a geological depression oriented in the direction South South-East – North North-East (SSO-NNE), bordered from the west by the Yammouneh fault, and from the east by the Serghayah fault. To the east of the Serghayah fault, the Cenomanian outcrops on the Anti-Lebanon Range. To the south-west, the Jurassic Barouk formation outcrops in the Mount-Lebanon Range, then the Cenomanian in the north-west is separated from the Jurassic by a series of transversal faults at the level of Dahr el Baidar – Chtaura (Figure 73).

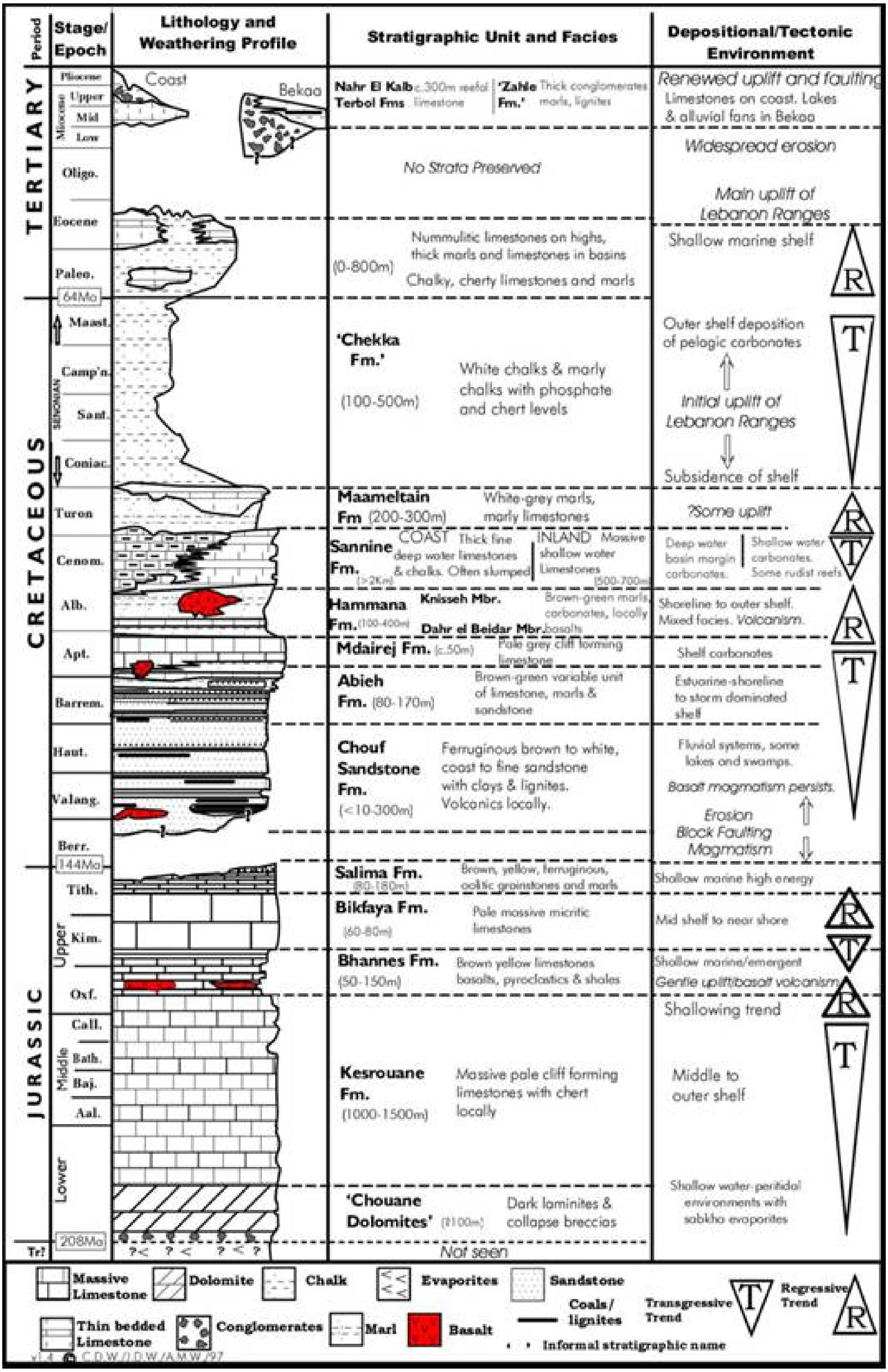

Figure 73. Geological Formations of Lebanon (Walley, 1997)

The majority of the Beqaa Plateau is dominated by the *Quaternary alluviums* overlaying the *Neogene Conglomeratic* formation, which in turn covers a SW-NO syncline outcropping to east and west of the Plateau with the succession of the Cenomanian-Turonian, Sennonian, and Eocene.

The *Middle Cretaceous* rocks are characterized mainly by the Cenomanian formation (C4) called also the Sannine Limestone. This formation is approximately 600 m thick (Dubertret, 1955). It is constituted of three litho-stratigraphical units. These are from bottom to top of the stratigraphical sequence: (a) the lower Cenomanian unit (C4-1) which is essentially dolomitic; (b) the middle Cenomanian unit (C4-2) constituted of a limestone cliff marking the base of the unit, an alternation of beige dolomitic limestone beds (with siliceous nodules and bands) and grey dolomitic beds; and ocre to brown dolomitic, and (c) the Upper Cenomanian Unit (C4-3) entirely dolomitized to the west of the valley while it is dolomitic limestone to the east.

The *Turonian Rock* (*C5*) formation is mainly constituted of limestone and dolomitic limestone. It is separated from the Cenomanian by a layer of marl. The *Sennonian* (*C6*) outcrops along the Anti-Lebanon ridge to the South-East and from Wadi El Aarayech-Zahleh to Chmistar in the North West of the valley. The Sennonian consists of marls, limy-limestone and marly-limestone rocks. The *Neogene* is laid unconformably of the top of the Cretaceous rocks, and followed by the *Quaternary* alluviums. The Neogene-Quaternary complex has a stratigraphic thickness that might reach 1,000 m next to Damascus Road (UNDP, 1970).

Mainly six aquifers can be distinguished within the upper Litani Basin. These are:

- The limestone aquifer of the Jurassic of in the Mount Lebanon Range.
- The limestone aquifer of the Cenomanian of in the Mount Lebanon Range.
- The limestone aquifer of the Cenomanian of in the Anti-Lebanon Range.
- The limestone aquifer of the Eocene in the Mount Lebanon Range.
- The limestone aquifer of the Eocene in the Anti-Lebanon Range.
- The alluvial aquifer of the Neogene-Quaternary complex.

The Jurassic Barouk Aquifer is mainly fed by the rain and snow pack over the Barouk Mountain. It flows towards the west where it reaches the Yammouneh fault and overflows in the form of numerous springs in Chtaura, Ammiq, Saghbine, and Kefraya. Both the Mount Lebanon and Anti Lebanon Cenomanian aquifers are characterized by significant karstification since the observed hydraulic gradients are very low (UNDP, 1970). The Eocene Aquifer (e) of Mount Lebanon is of limited extent since it extends between Zahleh and Chmistar to the North-East over a distance of 18 km and an outcropping average width of 0.5 km. It is a small aquifer of 9 km^2 entirely within the Litani basin (UNDP, 1970). The aquifer is formed of karstified limestone. The Eocene aquifer of the Anti-Lebanon lays partly within the Upper Litani catchment and partly within the Lower Litani catchment. It feeds the springs of Ras El Ain (Terbol), Ain Faour, Ain El Baida. The Neogene-Quaternary aquifer corresponds practically to the aquifer laying within the Beqaa Valley with a length of 65 km within the Litani Basin and an average width of 10 km. This aquifer flows towards the South-West feeding the Eocene aquifer. It is fed from rainwater, the return flow from irrigation and the exchange with the Litani River and its tributaries.

Appendix C. List of documented sources of pollution

Code	E	N	Village	Category	Description
1WF001	35.70547	33.55442	Qaroun	Industry	Olive oil Press
1WF002	35.70962	33.56942	Saghbine	Dumpsite	Waste Disposal
1WF003	35.73475	33.63305	Khirbet Kanafar	Dumpsite	Waste Disposal
1WF020	35.81929	33.68056	Ghazze	Dumpsite	Waste Disposal
1WF023	35.79802	33.66315	Mansoura	Dumpsite	Waste Disposal
1WF031	35.90326	33.72433	Anjar	Industry	Sugar factory
1WF043	35.80665	33.76289	Mazrait Bmohray	Industry	SICOMO factory
1WF046	35.82222	33.79753	Kabelias	Industry	Arak Touma factory
1WF064	35.83812	33.81501	Chtaura	Industry	Food Processing
1WF072	35.83907	33.82462	Jdita	Industry	Milk Processing
1WF076	35.85117	33.80964	Chtaura	Industry	Brick processing
1WF089	35.87793	33.87895	Qaa el Rim	Industry	Tissue Paper processing
1WF092	35.87777	33.87751	Qaa el Rim	Industry	Cardboard
1WF102	35.91291	33.82824	Zahle	Industry	Dairy Slaughter House
1WF110	35.91291	33.80056	Zahle	Landfill	Solid Waste Management
1WF165	35.97766	33.85885	Ablah	Industry	Tanmiya
1WF182	35.94446	33.85573	Ferzol	Industry	Potato Processing
1WI044	35.80958	33.76254	Mazrait Bmohray	Industrial discharge	SICOMO factory
1WR018	35.78078	33.64182	Jib Jannine	Dumpsite	Waste Disposal
1WR019	35.81932	33.66961	Ghazze	Waste water discharge	Into Litani River
1WR022	35.81790	33.67788	Mansoura	Waste water discharge	Into Litani River
1WR025	35.84616	33.73072	Houch el Harimeh	Dumpsite	Waste Disposal
1WR026	35.87199	33.74189	Houch el Harimeh	Industrial discharge	Sugar factory
1WR042	35.81607	33.74792	Tal el Akhdar	Waste water discharge	Normal Flow point
1WR055	35.83371	33.80450	Mekse	Waste water discharge	Into Mekse river
1WR056	35.85050	33.78524	Qabelias	Waste water discharge	Into Mekse river
1WR060	35.83704	33.81523	Mekse	Waste water discharge	Into earthen canal
1WR065	35.83785	33.81468	Chtaura	Industrial discharge	Into concrete channel
1WR068	35.84204	33.81401	Jdita	Waste water discharge	Into Jdita river
1WR069	35.85229	33.81564	Chtaura	Waste water discharge	Normal Flow point
1WR077	35.85312	33.80639	Chtaura	Industrial discharge	Brick Processing
1WR084	35.86183	33.82106	Taalabaya	Waste water discharge	Into Jalala river
1WR087	35.86477	33.80455	Taanayel	Waste water discharge	Normal Flow point
1WR091	35.87607	33.87830	Qaa el Rim	Industrial discharge	Pulp processing
1WR103	35.90239	33.82085	Zahle	Waste water discharge	Into Berdouni
1WR106	35.89396	33.81227	Saadnayel	Waste water discharge	Into Berdouni
1WR107	35.89151	33.80783	Saadnayel	Waste water discharge	Into Berdouni
1WR108	35.89216	33.79505	Taalbaya	Waste water discharge	Into Berdouni
1WR109	35.93982	33.81418	Zahle	Waste water discharge	Normal Flow point
1WR111	35.91618	33.79552	Zahle	Landfill runoff	Into Litani River
1WR112	35.91793	33.79706	Zahle	Waste water discharge	Into Litani River
1WR117	35.89359	33.75999	Barelias	Waste water discharge	Into Ghzayyel river
1WR118	35.90479	33.75954	Barelias	Waste water discharge	Into Ghzayyel river
1WR128	35.98914	33.86356	Ablah	Waste water discharge	Into Litani River
1WR130	35.99906	33.86830	Temnin Tahta	Waste water discharge	Into Litani River
1WR131	36.01956	33.89011	Bidnayel	Waste water discharge	Into Litani River
1WR132	36.02360	33.88513	Bidnayel	Waste water discharge	Into Litani River
1WR133	36.02444	33.88667	Qsarnaba	Dumpsite	-

Code	*E*	*N*	*Village*	*Category*	*Description*
1WR134	36.02736	33.88805	Houch el Ghanam	Waste water discharge	Into Litani River
1WR136	36.03586	33.90154	Bidnayel	Waste water discharge	Into Litani River
1WR137	36.03634	33.90200	Chehaymiye	Waste water discharge	Into Litani River
1WR140	36.06083	33.94364	Houch Bai	Waste water discharge	Into Litani River
1WR141	36.07942	33.97029	Hadath Baalbeck	Waste water discharge	Into Litani River
1WR142	36.07983	33.97468	Hadath Baalbeck	Industrial discharge	Into Litani River
1WR143	36.07992	33.96872	Hadath Baalbeck	Waste water discharge	Into Litani River
1WR144	36.07958	33.96608	Hadath Baalbeck	Waste water discharge	Into Litani River
1WR145	36.06660	33.94651	Houch en Nabi	Industrial discharge	Into Litani River
1WR146	36.08396	33.93810	Houch en Nabi	Industry	Into ditch
1WR154	35.98436	33.84647	Rayyak	Waste water discharge	Into Hala river
1WR155	35.98857	33.84642	Rayyak	Dumpsite	Waste Disposal
1WR157	35.96352	33.84064	Dalhamiye	Waste water discharge	Into Litani River
1WR162	35.97805	33.85488	Ablah	Waste water discharge	Into Litani River
1WR163	35.97944	33.85611	Ablah	Industrial discharge	Tanmiya
1WR164	35.98010	33.85638	Ablah	Industrial discharge	Tanmiya
1WR169	35.94432	33.82151	Dalhamiye	Waste water discharge	Into Litani River
1WR171	35.95435	33.83691	Karak	Waste water discharge	Into Litani River
1WR172	35.91307	33.80082	Zahle	Waste water discharge	Into Litani River
1WR173	35.77760	33.63640	Jib Jannine	Waste water discharge	Into Litani River
1WR211	35.94022	33.81450	Zahle	Industrial discharge	Discharge from poultry slaughterhouse on litani
1WR219	36.04365	33.91360	Haouch El rafqa	Waste water discharge	WW Houch el Rafqa area
1WR228	35.92355	33.79992	Zahle	Industrial discharge	Rock cutting industry, upstream zahle landfill

Appendix D. List of sampled surface water locations

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
1WF064	35.83812	33.81501	926	Food Processing	East to main entrance (below road)
1WF072	35.83907	33.82462	976	Milk Processing	Mazeri Taanayel facility and effluent discharge (canal adjacent to facility)
1WF076	35.85117	33.80964	896	Brick processing	Facility in Chtaura
1WF079	35.85340	33.81396	903	Mais Hospital	Between 1WR069, and 1WR070
1WF089	35.87793	33.87895	1221	Tissue Paper processing	Mimosa premises
1WF092	35.87777	33.87751	1190	Cardboard	Factory near Mimosa
1WF102	35.91291	33.82824	915	Dairy Slaughter House	Slaughter house premises - non operating in the mean time - under construction
1WF110	35.91291	33.80056	869	Solid Waste Management	Landfill premises
1WF165	35.97766	33.85885	934	Tanmiya	Poultry industry
1WF182	35.94446	33.85573	913	Potato Processing	Master Chips premises - factory discharge outlets on stormwater channelised runoff - factory discharges grease and oil into channel and adjacent vineyards - (distinguished grease smell) - flowing and discharging at 1WR171
1WF226	36.08363	33.97530	980		Dairy Farm - Milk Processing Unit
1WI044	35.80958	33.76254	884	SICOMO factory	Effluent is discharged into an earthen canal, meets with water from Ayn el Shatawiyeh, forms a combined flow and enters a pipe that discharges in Nahr Kabelias
1WR001	35.67782	33.57805	1023	Spring in Bab Mareh	Ain el Dib - Next to road, source in mountain, no residential area above or below
1WR002	35.66959	33.56064	1044	Spring in Aitanit	Ain Aitanit - Next to road, source in mountain, water discharges through village, no wastewater effluent
1WR003	35.72430	33.56466	962	Spring in Qaroun	Ain el Dayr - next to road, upper village area, close to Seha,
1WR004	35.72154	33.61354	857	Normal Flow point	Bridge in Saghbine above Litani River (River, lake bottle neck before 1WR005)

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
1WR005	35.71750	33.61596	849	Joint of Ain el Asafir with Litani	Ain el Asafir has minimal flow in dry season - currently it joins with Ain el Berde(Saghbine-and source just few meters from river))few meters before the junction (no junction during dry season)
1WR006	35.71702	33.62020	878	Spring in Ain Zebde	Ain el Asafir spring - Seasonal
1WR007	35.69900	33.61156	1019	Spring in Saghbine	Ain el Tayyoun - spring running under village with septic tanks
1WR008	35.69581	33.60780	1015	Spring in Saghbine	Ain el Ghazire - spring running under village with septic tanks
1WR009	35.69379	33.61256	1018	Spring in Saghbine	Ain el Rmayl - at higher elevations than village
1WR010	35.68953	33.60975	1123	Spring in Saghbine	Ain Chou'a - at higher elevations than village
1WR011	35.70115	33.62415	1102	Spring in Ain Zebde	Ain el Asafir spring - source above village, point location is before fisheries
1WR012	35.70577	33.62466	1019	spring in Ain Zebde	Ain el Asafir spring - below village - passes through fisheries
1WR013	35.71246	33.62872	983	Spring in Ain Zebde	Used for irrigation
1WR014	35.71880	33.63013	985	spring in Khraizat area	Khraizat spring source - below road - behind Hotel Khraizat
1WR015	35.74673	33.62890	871	runoff	point is below West Bekaa Country Club (probably carries wastewater discharge ??)
1WR016	35.77954	33.63873	853	Normal Flow point	Jib Jannine Bridge - point is after Kamed el Louz wastewater discharge point, and before Jib Jannine wastewater discharge point
1WR017	35.77915	33.63749	851	Normal Flow point	Point is downstream of 1WR016 and upstream of 1WR173
1WR018	35.78078	33.64182	856	Waste Disposal	On Litani river - adjacent to Kamed el Louz wastwater discharge point on Litani
1WR019	35.81932	33.66961	873	Into Litani River	Combined wastewater discharge point of Ghazze and Louce
1WR021	35.81829	33.67977	870	Normal Flow point	Bridge between Mansoura and Ghazze (location is before Ghazze and Louce wastwater discharge on Litani, and after Ghazze waste disposal site)
1WR022	35.81790	33.67788	869	Into Litani River	Wastewater effluent point in Mansoura
1WR024	35.83102	33.72910	863	Joint of	On the Spot!

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
				Ghzayel with Litani	
1WR025	35.84616	33.73072	862	Waste Disposal	On Ghzayyel River (Houch el Harimeh only)
1WR026	35.87199	33.74189	862	Sugar factory	Industrial effluent of Sugar factory in Houch el Hrimeh ?? - approximate location not located - No photos
1WR027	35.86957	33.74299	862	Normal Flow point	Bridge in Houch el Hrimeh above Ghzayyel River
1WR028	35.95697	33.74433	863	Chamsine Spring	Point is at the spring source
1WR029	35.94617	33.73266	879	Ghzayel River - Anjar Spring	Behind MoA fisheries
1WR030	35.91208	33.75501	869	Normal Flow point	Bridge over Ghzayyel (or referred to as Dayr Zanoun) between Bar Elias and Anjar
1WR032	35.76122	33.69443	894	runoff	Rainfall runoff generated in Dayr Tahnish - crossing main road in pipes and along earthen channels
1WR033	35.77025	33.68996	890	runoff	rainfal runoof generated from A'ana and Ain el Taym
1WR034	35.79448	33.69617	875	runoff	Spiro canal (earthen canal) - combined flow of 1WR033/1WR032 along with agricultural land drainage that discharges into litani - at 1WR038
1WR035	35.81999	33.70002	874	joint on Litani	Rainfall runoff generated in Ammiq along with Ain Abed flow (Ammiq) and agricultural drainage is collected in an earthen pond that diverges into: Main stream, Khandaq el Snoune, and part of Riyashi river
1WR036	35.82637	33.70397	872	Joint on Litani	Earthen canal discharging Ammiq swamp water - (called Nahr el Riyashi), agricultural drainage, and other tributaries fom Tal el Akhdar, and Kab Elias Area
1WR037	35.77289	33.71881	900	Spring in Ammiq	Ain Abed - not at source location but on a point where no developments exist - used for drinking water supply in A'ana, Ammiq, and Dayr Tahnish
1WR038	35.81705	33.68752	867	joint on Litani	Combined flow of 1WR032/1WR033 join to form Spiro Canal that discharges on Litani
1WR039	35.81828	33.69467	867	Joint on Litani	Kahndaq el Snoune - flow from earthen pond and agricultural drainage discharging on Litani further down (upstream)
1WR040	35.82996	33.73429	866	Normal Flow point	Small bridge over Ga'ayr river - carrying runoff from Chtaura, Jdita, Zebdol, Mikse and Kabelias
1WR041	35.82172	33.74220	865	Normal Flow point	Small bridge over Nahr el Shatawy formed by agricultural drainage only in earthen canal (hence the name)
1WR042	35.81607	33.74792	867	Normal Flow	Bridge over Kabelias river (or el Hafir river) carrying rainfall runoff of

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
				point	Kabelias area along with wastewater discharge in the river PLUS SICOMO industrial effluent discharge that joins under bridge with Hafir through drainage canal
1WR045	35.81223	33.79827	982	Spring in Kabelias	Ras el Ayn - source of Kabelias river
1WR047	35.82337	33.79686	911	Normal flow point	Bridge in Kabelias on Nahr Kabelias
1WR048	35.82564	33.79080	910	Normal Flow point	Bridge in Kabelias - spot supposedly where few wastewater discharge from Interior Ga'ayr river dischrges on the spot!
1WR050	35.89281	33.77757	896	Normal Flow point	Bridge over Litani river on Chtaura El Marj Road
1WR051	35.87878	33.76825	888	Normal Flow point	Bridge over Litani river, downstream of junction between combined Chtaura/Berdouni river, and Litani river.
1WR052	35.88342	33.77256	886	Joint on Litani	Berdouni/Chtaura combined flow joining Litani river at this spot
1WR053	35.83027	33.80959	936	Normal Flow point	Bridge over Mekse river on Qabelias/Chtaura road
1WR054	35.83363	33.80417	905	runoff	Next to Syrian Checkpoint - downstream of Mekse wastewater discharge into Mekse river
1WR055	35.83371	33.80450	906	Into Mekse river	Wastewater discharge outlet of Mekse in Mekse river
1WR056	35.85050	33.78524	871	Into Mekse river	Wastewater discharge of Mekse and Qabelias? On Mekse river just before junction of Mekse river and Gair river
1WR057	35.85056	33.78511	872	Joint of Mekse and Gair	Joint outside El Qasr area
1WR058	35.85780	33.76307	870	Normal Flow point	bridge over Mseel (drainge from Taanayel area) before junction with Gair river
1WR059	35.86825	33.76884	869	Normal Flow point	Point on Mseel after Ceramico Factory
1WR060	35.83704	33.81523	942	Into earthen canal	Discharge pipe on main road adjacent to Conserua Chtaura
1WR061	35.83412	33.82454	967	Spring in Jdita	Naba'a Jdita
1WR062	35.84035	33.81779	931	Normal Flow point	Bridge over Naba'a Jdita on Chtaura road (Jdita junction)
1WR063	35.81421	33.83827	920	Normal Flow point	junction between 1WR060 and 1WR065 below Conserua Chtaura

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
1WR065	35.83785	33.81468	927	Into concrete channel	Effluent can be seen discharging into channel leading to earthen canal
1WR066	35.84136	33.81324	919	Spring in Chtaura	Supposedly joins with Zebdol river (downstream part of Jdita spring)
1WR067	35.84347	33.81049	912	Zebdol river	Point on Zebdol river
1WR068	35.84204	33.81401	925	Into Jdita river	Upstream of 1WR067
1WR069	35.85229	33.81564	910	Normal Flow point	Wastewater discharge from Jdita and Chtaura? - Facing Masebki Hotel
1WR070	35.85229	33.81179	904	Normal Flow point	Bridge over Chtaura river downstream of 1WR069
1WR071	35.83871	33.82493	978	Normal Flow point	Channelised stormwater that discharges into Jdita river - point is upstream of 1WF072
1WR073	35.84745	33.81583	932	Normal Flow point	Channelised rainfall runoff east to Checkpoint
1WR074	35.85058	33.81179	914	Normal Flow point	Downstream of 1WR073
1WR075	35.85086	33.82405	892		Chtaura Spring source
1WR077	35.85312	33.80639	890	Brick Processing	Effluent of Brick factory discharges at this location
1WR078	35.85692	33.80005	885	Normal Flow point	Bridge is downstream of 1WR077 - 2 wastewater discharge pipes from Chtaura - Pipe 1 (Jdita - Chtaura Taanayel? photos 199, 200) Pipe 2(Taanayel, Chtaura, Cheberiyye photos 201, 202) Bridge photos (197, 198) Bridge is called Cheberiyye Bridge
1WR080	35.87420	33.78082	870	Normal Flow point	Bridge over combined flow of Chtaura river and Jalala river before Dayr Taanayel area
1WR081	35.87596	33.78240	872	Normal Flow point	Bridge over canal discharging from Taanayel pond (in addition to agricultural drainage) outside Dayr Taanayel premises
1WR082	35.88464	33.77586	870	Normal Flow point	Junction between Berdouni River and Chtaura river
1WR083	35.85658	33.84010	997	Normal Flow point	Runoff generated in upper Jalala area
1WR084	35.86183	33.82106	915	Into Jalala river	Stormwater? Discharge pipe in upper Taalabaya into Jalala river
1WR085	35.86152	33.81637	908	Normal Flow point	Bridge over Jalala river on Saadnayel road

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
1WR086	35.86296	33.80832	892	Normal Flow point	Bridge over jalala river in Jalala
1WR087	35.86477	33.80455	886	Normal Flow point	Jalala river crossing Chtaura - El Marj road before entering Dayr Taanayel area and joining Chtaura river. Taanayel discharges wastewater into this river
1WR088	35.87142	33.88750	1237	Berdouni Spring	Spring Source in Qaa el Rim - location is on bridge next to well heads
1WR090	35.87541	33.87915	1177	Normal Flow point	Bridge is upstream of Mimosa industrial effluent discharge point
1WR091	35.87607	33.87830	1180	Pulp processing	Mimosa effluent on Berdouni spring through concrete channel with outlet into earthen canal before discharging into Berdouni
1WR093	35.88002	33.86970	1096	Normal flow point	Point is near Muntazah Wadi El Rim on Berdouni river downstream of Mimosa factory
1WR094	35.88780	33.86404	1035	Normal flow point	Bridge is over Berdouni in upper Wai el Arayesh area
1WR095	35.89280	33.85754	996	Normal flow point	Point is on Berdouni river before entering Wadi el Arayesh restaurants area
1WR096	35.89486	33.85426	985	Normal flow point	Point on Berdouni after leaving Wadi el Arayesh restaurants area
1WR097	35.89627	33.85121	976	Normal flow point	Bridge over Berdouni in Zahle - adjacent to Red Cross
1WR098	35.90515	33.84483	949	Normal Flow point	Bridge over Berdouni in Zahle - adjacent to Zahle Water Authortiy
1WR099	35.91212	33.83864	933	Normal flow point	Bridge over Berdouni in Zahle - adjacent to statue on main roundabout
1WR100	35.91346	33.83215	922	Normal Flow point	Bridge over Berdouni in Zahle after crossing Zahle - Baalbeck road (downstream of 1WR099)
1WR101	35.91001	33.82605	911	Normal Flow point	Bridge over Berdouni in Zahle - downstream of Slaughter (no operating) house
1WR103	35.90239	33.82085	893	Into Berdouni	Wastewater discharge into Berdouni river from Ksara? Area and upper (SW) Zahle? area
1WR104	35.90067	33.81928	894	Normal Flow point	Bridge over Berdouni river downstream of 1WR103 close to Electrical Power plants
1WR105	35.89806	33.81674	887	runoff	Stormwater discharge from Ksara area - adjacent school discharges wastewater into canal
1WR106	35.89396	33.81227	884	Into Berdouni	Wastewater discharge from Saadnayel into Berdouni through unfinished pipe network

Code	E (DD)	N (DD)	Elevation (m)	Description	Remarks
1WR107	35.89151	33.80783	882	Into Berdouni	Wastewater discharge from Saadnayel into Berdouni through pipe
1WR108	35.89216	33.79505	878	Into Berdouni	Point is upstream to Wastwater discharge from Taalbaya through pipe and open channel - discharge location is unaccessible at current date
1WR109	35.93982	33.81418	884	Normal Flow point	Runoff from Zahle industrial area near bridge on Zahle-Terbol road
1WR111	35.91618	33.79552	877	Into Litani River	Discharge from Landfill through earthen canal into pipe section into Litani river with flows from inside Landfill area (probably drainage or leaching)
1WR112	35.91793	33.79706	884	Into Litani River	Wastewater discharge through earthen earthen channel into Litani river on Northern boundary of Zahle Landfill (probably discharge through Zahle main wastewater pipe?)
1WR113	35.92562	33.80120	880	Normal Flow point	Point is upstream of Landfill site on Litani river
1WR114	35.91299	33.79168	882	Normal Flow point	Point is downstream of Landfill site on Litani river
1WR115	35.90401	33.78302	884	Normal Flow point	Point is on Litani river downstream of Landfill site before entering Barelias area
1WR116	35.89395	33.76074	870	Normal Flow point	Joint of Khandaq Khouaizeq (agricultural drainage from Barelias area) with Ghzayyel river
1WR117	35.89359	33.75999	869	Into Ghzayyel river	Barelias wastewater discharge into Ghzayyel river downstream of 1WR116 - pipe discharge location can be detected by turbulent flow on river surface (pipe under river surface)
1WR118	35.90479	33.75954	871	Into Ghzayyel river	Barelias wastewater discharge into Ghzayyel river upstream of 1WR116 - manholes can be seen clearly and pipe discharge cannot be clearly seen
1WR119	35.90726	33.76201	873	Normal Flow point	Bridge over Aaqaiber river (agricultural drainage from Barelias, and Terbol area) before joint with Ghzayyel river
1WR120	35.90640	33.75887	873	Normal Flow point	Joint of Aaqaiber river with Ghzayyel river
1WR121	35.93230	33.75803	886	Normal Flow point	Point on Ghzayyel river downstream of junction between Nahr Faour and Nahr Chamsine
1WR122	35.94185	33.75379	867	Normal Flow point	Supposedly junction between Nahr Faour and Nahr Chamsine
1WR123	35.93541	33.75650	874	Normal Flow point	Supposedly junction between Nahr Faour and Nahr Chamsine
1WR124	35.94772	33.75809	876	Normal Flow point	Point is Nahr Faour behind Tellet Hamra? before upstream of 1WR122/123
1WR125	35.95121	33.76260	879	Normal Flow	Bridge over Nahr Faour West to Jbailet el Faour

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
				point	
1WR126	35.96823	33.78336	877	Normal Flow point	Bridge over Faour river on junction to Faour-Zahle road
1WR127	35.98903	33.86349	906	Normal Flow point	Bridge over Litani river on Ablah Riyyak road
1WR128	35.98914	33.86356	905	Into Litani River	Wastewater discharge pipe on Litani river probably from Tamnin Tahta?
1WR129	35.99945	33.86852	915	Normal Flow point	Bridge over Litani river on road from Temnin Tahta to Baalbeck highway
1WR130	35.99906	33.86830	912	Into Litani River	Wastewater discharge pipe into Litani river from Temnin Tahta and Temnin Fawqa
1WR131	36.01956	33.89011	939	Into Litani River	Wastewater discharge through pipes into earthen canal that discharges into Litani
1WR132	36.02360	33.88513	926	Into Litani River	Point is between earthen canal of 1WR131 and wastewater discharge pipe from Bidnayel into Litani river. (flow from pipe has a distinguished odour)
1WR133	36.02444	33.88667	928	Normal Flow point	Waste disposal site of Qsarnaba village
1WR134	36.02736	33.88805	929	Into Litani River	Wastewater discharge through pipe into Litani river probably from Hillaniye, Sariin, Nabi Shit?
1WR135	36.02825	33.89141	931	Normal Flow point	Bridge over Litani river behind El Tal, upstream of 1WR134
1WR136	36.03586	33.90154	935	Into Litani River	Wastewater discharge pipe from Bidnayel into Litani river through pipe
1WR137	36.03634	33.90200	938	Into Litani River	Wastewater discharge pipe into Litani river from Chehaymiye village
1WR138	36.03635	33.90204	939	Normal Flow point	Bridge over Litani river in Chehaimiye village
1WR139	36.04855	33.96078	1006	Ayn Houch Bai	Water source of spring
1WR140	36.06083	33.94364	964	Into Litani River	Wastewater discharge pipe into Litani from Chmistar
1WR141	36.07942	33.97029	988	Into Litani River	Wastewater discharge of Britel through canal into Litani river in Hadath Baalbeck area - upstream to this point, a milk processing farm discharges effluent through PE pipe into Litani
1WR142	36.07983	33.97468	985	Into Litani River	Point is discharge of PE pipe mentioned in 1WR141

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
1WR143	36.07992	33.96872	981	Into Litani River	Wastewater discharge of Britel into Litani river through pipe that overflows forming a swamp with distinguished wastewater that overflows into Litani
1WR144	36.07958	33.96608	980	Into Litani River	Wastewater discharge of Taraya village into Litani river through earthen canal - combined wastewater and stormwater
1WR145	36.06660	33.94651	964	Into Litani River	Wastewater discharge of Liban Lait into Litani river (no visual sighting for discharge of dairy products processing effluent)
1WR146	36.08396	33.93810	1001	Into ditch	Wastewater discharge of Liban Lait after leaving premises
1WR147	36.06112	33.94371	961	Normal Flow point	Bridge over Litani river downstream of 1WR145 and just upstream of 1WR140
1WR148	36.10226	33.99794	1000	Source	No overflow to Litani
1WR149	36.10470	34.00315	1000	Source	Spring overflows into Litani
1WR150	36.09446	34.02420	1001	Normal Flow point	Point is near control structure that regulates flow coming from Yammoune area through irrigation canal and discharges in Alaaq area forming first visual flow of Litani river (in Saaide area)
1WR151	36.09789	33.96774	991	Source	Hizzine Spring - forms a wetland and has minimal flow during dry periods
1WR152	36.08070	33.98044	984	Normal Flow point	Bridge over Litani river in Hizzine on Hizzine-Nabi Rachade road
1WR153	36.09312	33.99875	995	Normal Flow point	Bridge over Litani river in Hadath Baalbeck area upstream of Dalia effluent disposal location?
1WR154	35.98436	33.84647	871	Into Hala river	Wastewater discharge pipe on Hala river in Rayyak area combining flows from Masa, Haret al Fikani, Ali el Nahri, El-Nasiriyeh, Houch Hala, and Riyak
1WR155	35.98857	33.84642	879	Waste Disposal	Waste disposal site on Hala river from Rayyak
1WR156	35.96375	33.84068	874	Normal Flow point	Bridge over Litani river on Dalhamiye - Karak road
1WR157	35.96352	33.84064	877	Into Litani River	Wastewater discharge into Litani river frlom Ferzol?
1WR158	35.96943	33.84071	885	Normal Flow point	Bridge over Hala river before junction of Hala river with Litani
1WR159	35.96480	33.84169	885	Normal Flow point	Joint of Hala river with Litani
1WR160	36.12724	33.85924	1136	Normal Flow point	Point is on Yahfoufa river upstream of Chlorination unit - supposedly river has wastewater flows from Sirghaya village (e.p. 25000?) in Syria
1WR161	36.07909	33.85487	1020	Normal Flow point	Bridge over Yahfoufa river

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
1WR162	35.97805	33.85488	923	Into Litani River	Wastewater discharge of Ablah, Nabi Ayla, Eshli, thruogh earthen canal (after pipe outflows) into Litani river
1WR163	35.97944	33.85611	922	Tanmiya	Industrial effluent from Tanmiya into Litani river through pipe
1WR164	35.98010	33.85638	922	Tanmiya	Industrial effluent form Tanmiya
1WR166	35.96961	33.84642	918	Normal Flow point	Metal bridge over Litani river downstream of Tanmiya
1WR167	35.98159	33.85857	910	Normal Flow point	Point is upstream of Tanmiya facility (1WF165) and downstream of Ablah-Rayyak bridge (1WR127)
1WR168	35.94492	33.82219	894	Normal Flow point	Dalhamiye Bridge over Litani - downstream is bridge over Litani from Industrial area in Zahle towards Faour, and Upstream is bridge 1WR156 over Litani after Junction with Hala river)
1WR169	35.94432	33.82151	885	Into Litani River	Wastewater discharge into Litani river from Zahle Industrial area ? downstream of 1WR168
1WR170	35.94967	33.83072	889	Normal Flow point	Bridge over Litani river - upstream of Dalhamiye bridge
1WR171	35.95435	33.83691	890	Into Litani River	Wastewater discharge of Karak area into Litani river through pipes that overflow through manhole on main road and joins stormwater flow and Masterchips industrial effluent in an earthen channel - pipe can be seen in channel - and wastewater flow is on road
1WR172	35.91307	33.80082	877	Into Litani River	Start of Wastewater discharge channel in 1WR112 on Northern boundary of Landfill
1WR173	35.77760	33.63640	843	Into Litani River	Wastewater discharge form Jib Jannine into Litani river after flow passes through 3 cells
1WR174	35.78148	33.64182	845	Into Litani River	Water discharge into Litani river facing 1WR018 (probably including Kamed el Louz wastewater discharge through this earthen canal after pipe overflow)
1WR175	35.82027	33.75632	859	Normal Flow point	Point on Hafir river upstream of Sicomo discharge channel on Hafir near Tal el Akhdar
1WR176	35.82545	33.76617	874	Normal Flow point	Bridge over Hafir river in agricultural area
1WR177	35.82631	33.78425	893	Normal Flow point	Point is on Hafir river in Qabelias
1WR178	35.82653	33.77340	880	Normal Flow point	Point is on Hafir river downstream of all Qabelias wastewater discharge (upstream of 1WR176, and downstream of 1WR177)
1WR179	35.86620	33.74048	870	Joint on Ghzayyel	Point where Ghzayyel river is diverted into Nahr el Faregh for irrigation Houch el Harimeh agricultural land - at current date junction is closed until irrigation season

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
1WR180	35.85432	33.72379	870	Normal Flow point	Bridge over Nahr el Faregh in Houch el Harimeh upstream of Houch el Harimeh wastewater discharge location
1WR181	35.81885	33.69004	862	Normal Flow point	Junction of Nahr el Faregh with Litani river
1WR184	35.69166	33.56626			Qaroun Lake Samples
1WR185	35.69390	33.56591			Qaroun Lake Samples
1WR186	35.69624	33.56537			Qaroun Lake Samples
1WR187	35.68976	33.56046			Qaroun Lake Samples
1WR188	35.69234	33.55992			Qaroun Lake Samples
1WR189	35.69481	33.55957			Qaroun Lake Samples
1WR190	35.69343	33.55363			Qaroun Lake Samples
1WR191	35.69212	33.55487			Qaroun Lake Samples
1WR192	35.68844	33.55449			Qaroun Lake Samples
1WR193	35.69001	33.55037			Qaroun Lake Samples
1WR194	35.69613	33.58995			Qaroun Lake Samples
1WR195	35.69769	33.57125			Qaroun Lake Samples
1WR196	35.69521	33.57172			Qaroun Lake Samples
1WR197	35.69273	33.57212			Qaroun Lake Samples
1WR198	35.69918	33.57722			Qaroun Lake Samples
1WR199	35.69656	33.57764			Qaroun Lake Samples
1WR200	35.69415	33.57803			Qaroun Lake Samples
1WR201	35.69811	33.58348			Qaroun Lake Samples
1WR202	35.69565	33.58387			Qaroun Lake Samples
1WR203	35.70060	33.58302			Qaroun Lake Samples
1WR204	35.77433	33.63647	861		Litani river, Downstream Jib Jannine WW outlet
1WR205	35.81913	33.67525	868		Litani river, downstream mansoura ww and upstream ghazeh-louce ww
1WR206	35.81668	33.66874	865		Litani river, downstream ghazeh-louce ww
1WR207	35.88190	33.77048	867		Litani river, between 1WR051 and 1WR052
1WR208	35.86701	33.75748	871		Litany river, downstream 1WR051

Code	E (DD)	N (DD)	Elevation (m)	Description	Remarks
1WR209	35.83319	33.73334	874		Litany river, upstream ghzayel joint
1WR210	35.82924	33.72416	864		Litany river, downstream ghzayel joint
1WR211	35.94022	33.81450	875		Discharge from poultry slaughterhouse on litani
1WR212	35.93576	33.81039	882		Litani river, downstream 1WR109 and upstream 1WR113
1WR213	35.94418	33.81992	887		Litani river, upstream 1WR211 and downstream 1WR169
1WR214	35.96077	33.83937	901		Litani river, downstream ferzol ww
1WR215	35.97675	33.85397	899		Litani river, downstream ablah WW and tanmiya discharge
1WR216	35.98689	33.86210	907		Litani river, after riyak bridge, before tanmiya
1WR217	35.99633	33.86610	908		Litani river, downstream ww of tamnine tahta and fawqa
1WR218	36.02101	33.88306	921		Litani, downstream bednayel ww
1WR219	36.04365	33.91360	923		WW Houch el Rafqa area
1WR220	36.04078	33.90958	946		Litani river, downstream WW Houch el Rafqa
1WR221	36.04475	33.91732	950		Litani river, upstream WW Houch el Rafqa
1WR222	36.06736	33.94748	970		Litani river, upstream liban lait discharge
1WR223	36.06007	33.94263	967		Litani river, after chmistar ww
1WR224	36.07993	33.97488	993		Litani river, upstream milk processing PE pipe
1WR225	36.07962	33.96610	990		Litani river, downstream 1WR224
1WR227	35.91526	33.79437	880		Litani river, downstream zahle landfill
1WR228	35.92355	33.79992	882		Rock cutting industry, upstream zahle landfill
1WR229	35.82536	33.70185	864		Litani river after joint with Hafir/Gair combined flow
1WR230	35.82644	33.70582	866		Litani river - before joint with combined flow of Hafir/Gair river
1WR231	35.85281	33.81587	879		Chtaura river, before wastewater - Masabki hotel
1WR232	35.85333	33.81432	872		Chtaura river, downstream of 1WR069, and upstream of Mais Hospital
1WR233	35.85652	33.80059	890		Chtaura river, upstream of 1WR078
1WR234	35.85818	33.79960	888		Chtaura river, downstream of 1WR078
1WR235	35.90267	33.82097	906		Berdouni river, upstream of 1WR103
1WR236	35.89391	33.80965	885		Berdouni river, downstream of 1WR106, and upstream of 1WR107
1WR237	35.88930	33.80515	882		Berdouni river, downstream of wastewater discharge at 1WR107 near the

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
					dumpsite
1WR238	35.89295	33.79575	880		Berdouni river, upstream of 1WR108
1WR239	35.89282	33.79350	879		Berdouni river, downstream of 1WR108
1WR240	35.88301	33.77547	877		Chtaura river before joint with Berdouni
1WR241	35.88531	33.77615	875		Berdouni river before joint with Chtaura
1WR242	35.88361	33.77339	873		Combined Berdouni/Chtaura flow before joint with Litani (1WR052)
1WR243	35.88531	33.77367	871		Litani river, before joint with combined flow of Berdouni/Chtaura
1WR244	36.02702	33.85612	946		Hala river, in Ali Nahri village
1WR245	35.90172	33.75859	857		Ghzayyel river, downstream of 1WR118(WW discharge of Barelias are that could not be sampled since pipe is embedded in flow channel) and upstream of 1WR117
1WR246	35.89173	33.75962	864		Ghzayyel river, downstream of 1WR117 and 1WR118
1WR247	35.84161	33.81445	896		Jdita river, upstream of WW at 1WR068
1WR248	35.83370	33.80388	897		Mekse river, downstream of WW at 1WR055
1WR249	35.85051	33.78548	872		Jdita river, upstream of joint of Mekse and Jdita
1WR250	35.85057	33.78413	873		Gair river, downstream of joint of Mekse/Jdita river
1WR251	35.85184	33.76348	871		Gair river, downstream of joint of Mekse/Jdita river
1WR252	35.82355	33.79575	927		Qab Elias river, after leaving residential area near LRA station
1WR253	35.81575	33.74556	873		Hafir river, downstream of WW discharge and Sicomo effluent - in Tal Akhdar area (1WR042)

Appendix E. List of sampled groundwater wells

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Village*	*Use*	*Description*
1kG001	36.07756	33.92009	1010	Sifri	Drinking	*Inside an Agricultural area*
1kG002	36.07382	33.92456	998	Sifri/AREC	Drinking	*Near AREC*
1kG003	36.04805	33.92400	961	Housh Ar Rafqa	Drinking &Irrigation	*Place known as dao al kamar*
1kG004	36.05530	33.93122	968	Haoush An Nabi	Drinking &Irrigation	*Along the village main road*
1kG005	35.99184	33.86429	915	Rayak	Not certain	*Along the village main road*
1kG006	35.98105	33.86132	907	Ablah	Drinking	*Near the river*
1kG007	35.93137	33.82344	897	Zahle	Industrial	Stone Industry
1kG008	35.93487	33.81947	893	Zahle	Industrial	Beton Bekaa
1kG009	35.94758	33.80587	886	Zahle	Drinking &Irrigation	*Along the village main road*
1kG010	35.91776	33.82101	905	Haoush Al Oumara	Irrigation	*Along the village main road*
1kG011	35.90642	33.80479	881	Zahle	Drinking	Amreyeh Mosque
1kG013	35.89416	33.82650	897	Ksara	Drinking	Near Ksaara factory
1kG015	35.94747	33.79659	880	Bar Elias	Drinking	*Along the village main road*
1kG016	35.77193	33.64661	863	Joub Jannine	Drinking &Irrigation	1 km from landfill
1kG017	35.79990	33.63671	878	Joub Jannine	Drinking &Industrial	*Along the village main road*
1kG019	35.78334	33.63065	887	Joub Jannine	Drinking	*Along the village main road*
1kG020	35.79674	33.63057	899	Joub Jannine	Drinking &Irrigation	place known as Oushaysh
1kG021	35.71918	33.57243	907	Qaraoun	Industrial	Stone Industry
1kG022	35.70412	33.55269	872	Qaraoun	Industrial	Gas Station
1kG025	35.74793	33.58894	1118	Baaloul	Drinking	*Along the village main road*
1kG026	35.73071	33.58289	963	Baaloul	Drinking	Owned by Baladiyah
1kG029	35.91474	33.73409	891	Majdel Anjar	Drinking &Irrigation	*Along the village main road*
1kG030	35.90138	33.72290	884	Majdel Anjar	Industrial &Irrigation	Close to Sugar Factory
1kG032	35.83616	33.68617	869	Ghazze	Drinking &Irrigation	*Along the village main road*
1kG034	35.82273	33.66163	860	Ghazze	Irrigation	*Along the village main road*
1kG040	35.86752	33.67792	896	Dakoue	Drinking &Irrigation	Known as AL Rashidiyeh
1kG044	35.75659	33.65670	916	Kafraiya	Irrigation	Near Chateau Kefraya
1kG045	35.83778	33.80799	892	Meksi	Drinking	Known as Ain Al Sakhira-direction of gas factory
1kG046	35.83120	33.80239	909	Qabb Elias	Irrigation	Known as Hay Al Kuroum
1kG049	35.78341	33.71357	871	Housh Aammiq	Irrigation	Owned by Skaf family(place=AL Naoura)
1kG051	35.71386	33.63703	1057	Khirbet Qanafar	Drinking	*Along the village main road*
1kG053	35.77862	33.66232	878	Tall Znoub	Drinking	*Inside an Agricultural area*
1kG054	35.95381	33.84845	892	Fourzol	Irrigation	*Along the village main road*

Code	E (DD)	N (DD)	Elevation (m)	Village	Use	Description
1kG055	35.95678	33.84069	889	Fourzol	Irrigation	*Along the village main road*
1kG056	35.98797	33.86633	911	Nabi Aila	Irrigation	*Along the village main road*
1kG057	36.00709	33.85297	932	Rayak	Drinking	*Along the village main road*
1kG058	36.02967	33.87918	949	Housh El-Ghanam	Drinking &Irrigation	*Along the village main road*
1kG060	36.06812	33.91301	1005	Saraain et Tahta	Industrial	*Well owned by Al Mousawi Foundation*
1kG061	36.04334	33.94002	990	Housh Bay	Drinking	*Along the village main road*
1kG062	36.04855	33.95184	995	Housh Bay	Drinking	*Along the village main road*
1kG063	36.03778	33.96560	1090	Chmistar	Drinking	*Along the village main road*
1kG064	36.04679	33.95591	1012	Chmistar	Drinking &Irrigation	*Along the village main road*
1kG065	36.06395	33.95901	1006	Taraiya	Drinking	*Along the village main road*
1kG069	36.06807	33.98636	1019	Wadi Messerta	Irrigation	*Along the village main road*
1kG070	36.08908	33.97424	995	Hizzine	Drinking &Irrigation	*Along the village main road*
1kG071	36.10621	33.96174	1011	Hizzine(near Britel)	Drinking	*Along the village main road*
1kG072	36.12113	34.00339	1022	Houch Barada	Drinking	*Along the village main road*
1kG073	36.11052	34.00576	1012	Houch Barada	Drinking &Irrigation	*Along the village main road*
1kG074	35.90503	33.83354	918	Haoush Al Oumara	Drinking	*Along the village main road*
1kG075	36.02546	33.90393	936	Bednayel	Irrigation	*Along the village main road*
1kG076	35.71783	33.56647	883	Qaraoun	Drinking	*Along the village main road*
1kG077	35.88230	33.78640	870	Taanayel	Drinking &Irrigation	*Along the village main road*
1kG078	35.84594	33.70868	876	Housh Al harimeh	Irrigation	*Along the village main road*
1kG079	35.81344	33.77665	879	Qabb Elias	Drinking	*Along the village main road*
1kG080	35.81335	33.77274	876	Qabb Elias	Drinking	*Along the village main road*
1kG081	35.75543	33.60749	983	Lala	Industrial &Irrigation	*Along the village main road*
1kG082	35.76980	33.62584	917	Lala	Drinking	*Along the village main road*
1kG083	35.89319	33.72398	821	Majdel Anjar	Drinking &Irrigation	*Along the village main road*
1kG084	35.85589	33.66681	884	Tal Al Zaaazih	Drinking &Irrigation	*Along the village main road*
1kG085	35.77935	33.68399	895	Aana	Drinking &Irrigation	*Along the village main road*

Appendix F. List of soil samples location

Sample code	*GPS coordinates*		*Description*
	N	*E*	
1WO001	33.57672	035.71552	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
1WO002	33.58104	035.71507	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
1WO003	33.58431	035.71619	Qaraoun area, irrigated last year from GW. well. The year before from Canal 900 (scheme 1, Qaraoun), wheat cultivated
1WO004	33.57158	035.71420	Qaraoun area, irrigated from GW well only
1WO005	33.59161	035.72623	Qaraoun area, upstream Canal 900, irrigated last year from Canal 900 by direct pumping, previous years fallow
1WO006	33.60408	035.73769	Lala area, irrigated from Canal 900 (scheme 2, Lala)
1WO007	33.60931	035.74274	Lala area, irrigated from Canal 900 (scheme 2, Lala)
1WO008	33.61759	035.74764	Lala area, irrigated from Canal 900 (scheme 2, Lala)
1WO009	33.62271	035.75706	Lala area, not irrigated, almond cultivated
1WO010	33.62193	035.75748	Lala area, irrigated from Canal 900 (scheme 2, Lala), pea cultivated
1WO011	33.63854	035.78046	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Jannine-Kamed el Laouz)
1WO012	33.65019	035.79826	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Jannine-Kamed el Laouz)
1WO013	33.63784	035.80101	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Janine-Kamed el Laouz)
1WO014	33.62484	035.82811	Kamed el Laouz area, irrigated from GW well only
1WO015	33.62817	035.81718	Kamed el Laouz area, irrigated from Canal 900 (scheme 3, Jib Janine-Kamed el Laouz)
1WO016	34.02248	036.09513	Saaide area, irrigated from Yammouneh canal and groundwater well
1WO017	34.01690	036.09780	Saaide area, irrigated from Yammouneh canal and groundwater well
1WO018	34.00936	036.09583	Saaide area, irrigated from Yammouneh canal and groundwater well
1WO019	33.99851	036.09602	Saaide area, irrigated from Yammouneh canal and groundwater well
1WO020	34.00337	036.09921	Saaide area, irrigated from Yammouneh canal and groundwater well

Appendix G. Guidelines for sample collection[9]

1. Guidelines

The following general guidelines can be applied to the collection of water samples (to be analyzed for physical or chemical variables) from rivers and streams, lakes or reservoirs and groundwater:

- Before collecting any sample, make sure that you are at the right place. This can be determined by the description of the station, from the position of landmarks and, in lakes, by checking the depth. If samples must be taken from a boat, a sampling station may be marked by placing a buoy at the desired location; otherwise it is necessary to identify the sampling station by the intersection of lines between landmarks on the shore.
- Before collecting well water sample, re-inspect the well for damage, missing parts, and evidence of tampering.
- Do not include large, non-homogeneous pieces of detritus, such as leaves, in the sample. Avoid touching and disturbing the bottom of a water body when taking a depth sample, because this will cause particles to become suspended.
- Sampling depth is measured from the water surface to the middle of the sampler.
- Samples taken to describe the vertical profile should be taken in a sequence that starts at the surface and finishes at the bottom. When taking the sample at the maximum depth it is important to ensure that the bottom of the sampler is at least 1 m above the bottom.
- Do not lower a depth sampler too rapidly. Let it remain at the required depth for about 15 seconds before releasing the messenger (or whatever other device closes the sampler). The lowering rope should be vertical at the time of sampling. In flowing water, however, this will not be possible and the additional lowering necessary to reach the required depth should be calculated.
- A bottle that is to be used for transport or storage of the sample should be rinsed three times with portions of the sample before being filled. This does not apply, however, if the storage/transport bottle already contains a preservative chemical.
- The temperature of the sample should be measured and recorded immediately after the sample is taken.
- At any time that the sample bottles are not closed, their tops must be kept in a clean place.
- A small air space should be left in the sample bottle to allow the sample to be mixed before analysis.
- **Make sure you collected an adequate volume for subsequent laboratory analysis.**
- Collect a quality control sample for the whole sampling episode, preferably during the first couple of days, whereby one duplicate sample will be collected.
- All measurements taken in the field must be recorded in the field notebook before leaving the sampling station.
- All supporting information should be recorded in the field notebook before leaving the sampling station. Such conditions as the ambient air temperature, the weather, the presence of dead fish floating in the water or of oil slicks, growth of algae, or any unusual sights or smells should be noted, no matter how trivial they may seem at the time. These notes and observations will be of great help when interpreting analytical results.
- Samples should be transferred to sample bottles immediately after collection if they are to be transported. If analysis is to be carried out in the field, it should be started as soon as possible.

Samples for bacteriological analysis

Most of the guidelines for sampling for physical and chemical analyses apply equally to the collection of samples for bacteriological analyses. Additional considerations are:

- **Samples for bacteriological analyses should be taken in a sterile sampling cup and should be obtained before samples for other analyses.**
- **Care must be exercised to prevent contamination of the inside of the sampling cup and sampling containers by touching with the fingers or any non-sterile tools or other objects.**
- **Bottles in which samples for bacteriological analyses are to be collected (or transported) should be reserved exclusively for that purpose.**

[9] Adapted from UNEP/WHO, 1996. Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes.

2. <u>Procedures</u>

Sampling from a tap or pump outlet

1. Clean the tap. Remove any attachments that may cause splashing from the tap. These attachments are a frequent source of contamination that may influence the perceived quality of the water supply. Use a clean cloth to wipe the outlet and to remove any dirt.
2. **Open the tap. Turn on the tap to maximum flow and let the water run for 1-2 minutes. Turn off the tap. For wells, make sure a minimum of three water column volumes has been purged**
3. ***Note:* Some people omit the next two steps and take the samples at this stage, in which case the tap should not be adjusted or turned off, but left to run at maximum flow.**
4. **Sterilize the tap for 1 minute with a flame (from a gas burner, cigarette lighter or an alcohol-soaked cotton wool swab)-if practical.**
5. **Open the tap before sampling. Carefully turn on the tap and allow water to flow at medium rate for 1 - 2 minutes. Do not adjust the flow after it has been set.**
6. Fill the bottle. Carefully remove the cap and protective cover from the bottle, taking care to prevent entry of dust that may contaminate the sample. Hold the bottle immediately under the water jet to fill it. A small air space should be left to allow mixing before analysis. Replace the bottle cap.

Sampling water from a water-course or reservoir

Open the sterilized bottle as described in step 5 above.

1. Hold the bottle near its bottom and submerge it to a depth of about 20 cm, with the mouth facing slightly downwards. If there is a current, the bottle mouth should face towards the current. Turn the bottle upright to fill it. Replace the bottle cap.

Appendix H. Lab analysis results

Appendix H1. Results of physico-chemical and microbiological analysis of surface water samples collected between February and April, 2005

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp (°C)*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NH_4 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*SO_4 (mg/L)*	*BOD_5 (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1WR001	25-Feb-05	Spring	7.66	12.9	8.9	148	0.01	0.011	14.4	0.01	0.007	30	0	0	0	0
1WR004	9-Mar-05	River	7.14	12.5	5.7	170	0.66	0.699	10.3	0.31	0.230	21	3.2	9	20,000	20,000
1WR005	25-Feb-05	Spring	7.66	16.3	8.43	202	0.03	0.032	10.8	0.02	0.015	57	0	0	150	150
1WR007	25-Feb-05	Spring	6.8	14	8.26	196	0.01	0.011	18.2	0.09	0.067	21	0	0	8	10
1WR011	25-Feb-05	Spring	7.48	13.9	7.8	235	0.01	0.011	1.7	0.01	0.007	115	0	0	4	7
1WR013	25-Feb-05	Spring	7.2	14.6	8.37	184	0.01	0.011	2.1	0.01	0.007	29	0	0	9	9
1WR014	25-Feb-05	Spring	7.05	15	8.45	164	0.01	0.011	1	0.08	0.059	7	0	0	1	3
1WR016	9-Mar-05	River	7.37	13.6	5.79	168	0.68	0.720	4.8	0.28	0.208	18	4.4	9	10,000	15,000
1WR021	9-Mar-05	River	7.6	13.7	6.97	165	0.66	0.699	5.8	0.21	0.156	17	4	6	7,000	11,000
1WR024	10-Mar-05	River	7.44	12.4	7.17	415	0.34	0.360	23.2	0.21	0.156	22	2	4	5,500	7,440
1WR027	6-Apr-05	River	7.23	15.4	7.87	216	0.25	0.265	19.7	0.17	0.126	18	2	2	5,000	6,750
1WR028	6-Apr-05	Spring	6.99	15.0	9.54	186	0.01	0.011	8.1	0.02	0.015	7	2	2	5	32
1WR029	6-Apr-05	Spring	7.52	14.4	9.60	194	0.01	0.011	10	0.09	0.067	9	2	2	11	25
1WR030	6-Apr-05	River	7.28	14.4	8.03	211	0.1	0.106	18.7	0.01	0.007	7	2	2	200	7,100
1WR036	21-Mar-05	River	7.22	13.1	5.55	200	0.1	0.106	4.9	0.16	0.119	10	2	2	8,800	10,000
1WR040	7-Apr-05	River	7.48	12.6	7.31	189	0.54	0.572	7.2	0.46	0.342	25	2.5	9	5,000	7,150
1WR045	7-Apr-05	Spring	7.74	12.2	8.92	129	0.08	0.085	4.9	0.28	0.208	19	2	5	800	800
1WR050	10-Mar-05	River	7.56	9.7	8.45	378	1.28	1.355	13	0.49	0.364	20	5.1	19	9,500	16,000
1WR051	10-Mar-05	River	7.67	9.7	8.61	327	0.84	0.889	9.3	0.27	0.201	19	3.1	12	8,500	16,000
1WR052	10-Mar-05	River	7.8	9.3	8.98	266	0.44	0.466	4.7	0.1	0.074	15	2	9	6,500	18,000
1WR053	7-Apr-05	River	7.83	12.3	9.80	164	0.41	0.434	3	0.33	0.245	15	2	6	13,450	15,000
1WR057	7-Apr-05	River	7.73	11.9	9.33	183	3	3.176	8.8	1.21	0.899	21	10	18	35,000	35,000
1WR061	7-Apr-05	Spring	6.83	12.4	9.08	125	0.01	0.011	6.9	0.06	0.045	10	2	2	24	54
1WR067	7-Apr-05	River	7.35	9.8	9.08	159	0.55	0.582	5.9	0.94	0.698	10	10	20	40,000	40,000
1WR070	23-Mar-05	River	7.5	15.3	7.28	165	0.24	0.254	4.8	0.78	0.580	9	45	116	18,500	25,000
1WR075	23-Mar-05	Spring	7.01	11.8	9.21	148	0.02	0.021	9	0.05	0.037	9	2	2	14	39
1WR080	23-Mar-05	River	7.48	13	7.73	155	0.02	0.021	7.3	0.25	0.186	21	12	22	14,000	16,000

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp (°C)*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NH_4 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*SO_4 (mg/L)*	*BOD_5 (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1WR088	24-Mar-05	Spring	7.68	4.1	7.68	119	0.01	0.011	5.9	0.01	0.007	7	2	2	0	1
1WR093	24-Mar-05	River	7.9	9.6	7.9	119	0.11	0.116	9.2	0.03	0.022	8	2	2	3,040	9,120
1WR100	24-Mar-05	River	7.93	9.7	7.93	128	0.02	0.021	6.7	0.02	0.015	8	2	7	9,920	10,000
1WR104	24-Mar-05	River	8.03	11.5	8.76	129	0.44	0.466	5.1	0.16	0.119	10	2.4	12	50,000	50,000
1WR111	18-Mar-05	Runoff	7.47	12.4	3.95	411	10.4	11.012	4.7	1.2	0.892	69	45	52	2	2
1WR113	18-Mar-05	River	7.61	15.7	6.64	272	3	3.176	28.1	0.91	0.676	30	10	27	110,000	110,000
1WR115	10-Mar-05	River	7.74	9.7	8.4	381	1.2	1.271	17.1	0.49	0.364	21	4.5	15	9,000	18,000
1WR126	6-Apr-05	River	7.18	13.3	8.62	262	0.13	0.138	49.7	0.14	0.104	24	2	2	2,900	5,400
1WR129	16-Mar-05	River	7.42	14.9	6.83	279	2.35	2.488	29	0.71	0.528	25	18	42	18,000	18,000
1WR135	16-Mar-05	River	7.55	15.4	7.49	234	2.2	2.329	27.7	0.8	0.594	20	8	14	13,000	16,000
1WR147	17-Mar-05	River	7.87	13.3	8.9	210	2.45	2.594	29.2	0.61	0.453	17	3	7	2,250	4,500
1WR150	18-Mar-05	Spring	7.79	10.3	8.35	114	0.02	0.021	4.9	0.03	0.022	7	2	5	113	272
1WR153	18-Mar-05	River	7.72	10.2	8.48	127	0.52	0.551	8.8	0.03	0.022	7	2	4	450	1,300
1WR155	4-Apr-05	River	7.71	9.7	10.00	151	0.1	0.106	4.5	0.18	0.134	27	2	2	6,600	9,250
1WR156	11-Mar-05	River	7.75	11.4	8.42	192	2.2	2.329	18.9	0.63	0.468	21	8	14	32,000	32,000
1WR159	11-Mar-05	River	8.06	11.4	8.76	151	1.6	1.694	9.5	0.45	0.334	22	8	16	28,000	28,000
1WR160	4-Apr-05	River	7.95	10.6	9.76	155	0.32	0.339	9.3	0.16	0.119	30	2	2	19,300	20,000
1WR161	4-Apr-05	River	7.84	10.5	12.00	156	0.25	0.265	8.5	0.21	0.156	29	2	2	5,100	7,800
1WR166	11-Mar-05	River	7.56	11.2	7.63	252	2.45	2.594	27.3	0.42	0.312	22	7	20	30,000	30,000
1WR168	11-Mar-05	River	7.72	9.9	8.45	207	1.5	1.588	18	0.42	0.312	22	8	14	32,000	32,000
1WR170	11-Mar-05	River	7.75	11.3	8.64	206	1.75	1.853	18.2	0.45	0.334	20	8	19	44,000	44,000
1WR178	7-Apr-05	River	7.83	14.0	8.47	136	0.18	0.191	5.5	0.16	0.119	21	4.9	10	35,000	35,000
1WR204	9-Mar-05	River	7.37	13.9	6	174	0.96	1.016	7.8	0.32	0.238	18	2	13	3,000	3,000
1WR205	9-Mar-05	River	7.6	13.4	6.9	167	0.68	0.720	8	0.22	0.163	19	2.3	7	5,960	7,000
1WR206	9-Mar-05	River	7.56	13.9	6.64	164	0.86	0.911	8.9	0.22	0.163	18	2	6	9,000	11,000
1WR207	10-Mar-05	River	7.69	9.7	8.6	320	0.88	0.932	8.3	0.33	0.245	18	2.3	16	11,500	17,000
1WR208	10-Mar-05	River	7.65	10.1	8.33	327	1.4	1.482	8.6	0.45	0.334	18	8	24	12,500	18,000
1WR209	10-Mar-05	River	7.7	10.4	8.31	318	1.14	1.207	5.4	0.28	0.208	18	4.5	18	8,500	16,000
1WR210	10-Mar-05	River	7.67	11.2	7.96	357	0.68	0.720	9	0.26	0.193	21	4.8	18	9,000	16,000

Sample ID	Date of sampling	Matrix	pH	Temp (°C)	DO (mg/L)	TDS (mg/L)	NH_3 (mg/L)	NH_4 (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)	P_2O_5 (mg/L)	SO_4 (mg/L)	BOD_5 (mg/L)	COD (mg/L)	FC (CFU/ 100 ml)	TC (CFU/ 100 ml)
1WR212	11-Mar-05	River	6.92	9.2	8.46	206	1.9	2.012	27	0.72	0.535	21	8	22	44,000	44,000
1WR213	11-Mar-05	River	7.64	9.6	8.37	203	1.4	1.482	20.5	0.35	0.260	22	8	19	18,000	32,000
1WR214	11-Mar-05	River	7.8	11.1	8.3	200	1.95	2.065	20	2.7	2.006	22	9	33	18,000	32,000
1WR215	16-Mar-05	River	7.45	13.3	7.43	270	4.2	4.447	26.4	1.04	0.773	25	15	38	50,000	50,000
1WR216	16-Mar-05	River	7.51	13.8	7.44	285	3.4	3.600	30	1	0.743	26	12	29	50,000	50,000
1WR217	16-Mar-05	River	7.15	17.7	6.48	285	2.9	3.071	29.4	0.75	0.557	26	15	39	24,000	24,000
1WR218	16-Mar-05	River	7.67	15.3	7.47	266	2.3	2.435	29	0.6	0.446	22	13	36	22,000	22,000
1WR220	17-Mar-05	River	7.46	11.7	8.22	232	1.6	1.694	35.4	0.59	0.438	19	5	8	35,000	40,000
1WR221	17-Mar-05	River	7.27	11	8.26	229	1	1.059	31	0.4	0.297	17	4	7	6,200	9,100
1WR222	17-Mar-05	River	7.78	12.2	9.62	197	0.12	0.127	41.6	0.09	0.067	16	2	2	1,950	4,200
1WR223	17-Mar-05	River	7.72	13.3	8.75	214	3.25	3.441	28.4	0.89	0.661	17	7	14	45,000	45,000
1WR224	17-Mar-05	River	7.92	14.2	8.87	151	0.07	0.074	19.5	0.02	0.015	9	2	2	650	750
1WR225	18-Mar-05	River	6.68	13.4	7.47	215	1.7	1.8	24	0.97	0.72	13.5	16	38.5	22,400	32,700
1WR227	18-Mar-05	River	7.54	15.2	6.6	270	4.3	4.553	26.7	1.06	0.788	31	17	37	120,000	120,000
1WR229	21-Mar-05	River	7.28	14.1	5.9	217	1.55	1.641	13.8	0.44	0.327	22	2	7	21,700	22,500
1WR230	21-Mar-05	River	7.48	14.9	6.61	228	1.15	1.218	19.1	0.52	0.386	22	2	5	14,000	15,000
1WR231	23-Mar-05	River	7.45	12	9.13	151	0.02	0.021	9.4	0.05	0.037	9	2	2	950	1,800
1WR232	23-Mar-05	River	7.5	12	8.64	225	0.44	0.466	8.2	0.67	0.498	15	16	28	25,400	27,500
1WR233	23-Mar-05	River	7.35	14.8	6.95	166	0.02	0.021	8.9	0.35	0.260	10	15	25	15,200	17,500
1WR234	23-Mar-05	River	7.37	14.2	6.84	170	0.02	0.021	7.8	0.39	0.290	7	28	53	18,000	20,000
1WR235	24-Mar-05	River	8.07	10.7	8.18	126	0.01	0.011	6.8	0.05	0.037	9	2	7	8,920	10,000
1WR236	24-Mar-05	River	8.08	10.8	9.42	131	0.4	0.424	7.5	0.21	0.156	9	3	7	33,200	35,000
1WR237	24-Mar-05	River	8.13	10.9	9.73	139	1.05	1.112	8.9	0.33	0.245	9	3.5	7	60,000	60,000
1WR238	24-Mar-05	River	8.18	11.5	9.47	147	1.05	1.112	8.4	0.31	0.230	13	3.8	11	45,000	50,000
1WR239	24-Mar-05	River	8.16	12.3	9.21	155	2.6	2.753	10.9	0.64	0.476	12	6.8	11	60,000	60,000
1WR240	24-Mar-05	River	7.83	13.1	9.44	178	0.03	0.032	7.1	0.15	0.111	21	2	27	10,850	17,550
1WR241	24-Mar-05	River	7.81	12	9.69	166	1.25	1.324	13	0.44	0.327	19	5.3	15	50,000	50,000
1WR242	24-Mar-05	River	7.75	12.8	9.4	165	1.3	1.376	10.3	0.37	0.275	20	3.7	10	32,000	32,500
1WR243	24-Mar-05	River	7.67	12.8	7.12	246	3.6	3.812	24.8	1.56	1.159	29	27.4	32	75,000	75,000

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp (°C)*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NH_4 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*SO_4 (mg/L)*	*BOD_5 (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1WR244	4-Apr-05	River	7.88	9.9	14.98	154	0.38	0.402	8.8	0.26	0.193	25	2	2	10,150	12,800
1WR245	6-Apr-05	River	7.34	14.4	8.34	210	0.23	0.244	21.8	0.11	0.082	18	2	2	9,600	12,800
1WR246	6-Apr-05	River	7.28	14.4	8.28	224	0.9	0.953	22	0.33	0.245	20	2	2	30,000	30,000
1WR247	7-Apr-05	River	7.54	10.3	9.93	160	0.42	0.445	3.4	0.89	0.661	11	10	20	30,000	30,000
1WR248	7-Apr-05	River	7.88	12.9	9.78	153	1	1.059	5.6	0.6	0.446	15	4.1	13	40,000	40,001
1WR249	7-Apr-05	River	7.64	10.9	9.18	152	0.4	0.424	5.8	0.96	0.713	14	12	24	45,000	45,000
1WR250	7-Apr-05	River	7.67	11.2	9.18	187	0.84	0.889	7.1	0.81	0.602	17	12	23	35,000	35,000
1WR251	7-Apr-05	River	7.64	11.1	8.50	174	0.52	0.551	7.2	0.41	0.305	18	2	15	35,000	35,000
1WR252	7-Apr-05	River	7.89	13.1	9.49	131	0.02	0.021	4	0.05	0.037	19	2	6	1,350	2,850
1WR253	7-Apr-05	River	7.62	13.9	8.74	148	0.76	0.805	8.5	0.39	0.290	27	12	24	25,000	25,000

Appendix H2. Results of physico-chemical and microbiological analysis of lake water samples collected between February and April, 2005

Sample ID	*Depth*	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NH_4 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*NO_3 (mg/L)*	*SO_4 (mg/L)*	*BOD_5 (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1WR184a	2/3d	2-Mar-05	Water	7.67	11.8	7.27	233	0.59	0.62	0.34	0.25	29.9	42	2	2	6	23
1WR184b	1/3d	2-Mar-05	Water	7.48	12	7.93	230	0.6	0.64	0.25	0.19	31.9	39	2	2	35	52
1WR185a	2/3d	2-Mar-05	Water	7.54	12	6.76	229	0.63	0.67	0.39	0.29	27.2	40	2	2	31	36
1WR185b	1/3d	2-Mar-05	Water	7.6	13.1	7.62	223	0.63	0.67	0.29	0.22	29.4	39	2	2	53	67
1WR186a	2/3d	2-Mar-05	Water	7.51	13.5	6.55	229	0.66	0.70	0.29	0.22	16.2	40	3	4	27	64
1WR186b	1/3d	2-Mar-05	Water	7.62	13.1	7.34	226	0.66	0.70	0.3	0.22	24.8	40	2	2	35	58
1WR187a	2/3d	2-Mar-05	Water	7.47	13.1	6.45	226	0.61	0.65	0.36	0.27	26.8	43	3	4	29	37
1WR187b	1/3d	2-Mar-05	Water	7.55	14.1	7.48	226	0.6	0.64	0.27	0.20	21.7	39	2	2	39	45
1WR188a	2/3d	2-Mar-05	Water	7.6	13	7.37	231	0.66	0.70	0.37	0.27	26.8	40	2	2	26	50
1WR188b	1/3d	2-Mar-05	Water	7.76	13.3	7.59	225	0.66	0.70	0.28	0.21	28.7	41	2	2	33	71
1WR189a	2/3d	2-Mar-05	Water	7.72	13.2	7.66	225	0.62	0.66	0.33	0.25	22.7	40	2	2	30	36
1WR189b	1/3d	2-Mar-05	Water	7.63	14.2	7.5	225	0.64	0.68	0.44	0.33	26.9	39	2	2	33	43
1WR190a	2/3d	3-Mar-05	Water	7.58	11.5	0.868	225	0.64	0.68	0.4	0.30	29.8	39	2	2	20	60
1WR190b	1/3d	3-Mar-05	Water	7.56	11.6	7.93	221	0.61	0.65	0.28	0.21	30.6	42	2	2	28	39
1WR191a	2/3d	3-Mar-05	Water	7.55	11.5	7.67	219	0.62	0.66	0.27	0.20	34.1	41	2	2	34	74
1WR191b	1/3d	3-Mar-05	Water	7.78	12.5	8.37	219	0.56	0.59	0.3	0.22	33.7	39	2	2	26	53
1WR192a	2/3d	3-Mar-05	Water	7.61	11.6	7.6	219	0.58	0.61	0.32	0.24	22.2	40	3	8	28	87
1WR192b	1/3d	3-Mar-05	Water	7.69	12.4	8.45	216	0.53	0.56	0.27	0.20	29.1	39	2	2	22	55
1WR193a	2/3d	3-Mar-05	Water	7.55	12.1	6.9	220	0.59	0.62	0.28	0.21	30.5	39	2	2	9	57
1WR193b	1/3d	3-Mar-05	Water	7.61	13	6.61	211	0.56	0.59	0.28	0.21	31.7	40	2	2	14	56
1WR194	mid	3-Mar-05	Water	7.78	16	6.6	214	0.51	0.54	0.26	0.19	31.4	37	2	2	18	96
1WR195	mid	7-Mar-05	Water	6.82	11.7	7.78	237	0.56	0.59	0.3	0.22	26.9	38	2	8	27	40
1WR196	mid	7-Mar-05	Water	7.38	12	8.04	235	0.58	0.61	0.3	0.22	30.6	39	2	5	30	48
1WR197	mid	7-Mar-05	Water	7.5	11.4	8.49	233	0.58	0.61	0.28	0.21	33	37	2	6	15	44
1WR198	mid	7-Mar-05	Water	7.48	11.5	7.44	238	0.54	0.57	0.27	0.20	29	37	2	10	16	37
1WR199	mid	7-Mar-05	Water	7.57	11.3	7.82	239	0.52	0.55	0.26	0.19	29.5	38	2	10	23	58
1WR200	mid	7-Mar-05	Water	7.7	11.9	8.41	239	0.53	0.56	0.29	0.22	27.9	36	2	9	76	90

Sample ID	*Depth*	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NH_4 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*NO_3 (mg/L)*	*SO_4 (mg/L)*	*BOD_5 (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1WR201	mid	7-Mar-05	Water	7.69	12.4	7.81	234	0.49	0.52	0.26	0.19	25.5	36	2	2	148	154
1WR202	mid	7-Mar-05	Water	7.69	12.2	7.65	234	0.54	0.57	0.26	0.19	24.6	37	2	8	196	208
1WR203	mid	7-Mar-05	Water	7.71	12.7	7.84	224	0.51	0.54	0.25	0.19	23.9	34	2	6	49	62
C900		24-Feb-05	Water	7.75	20.3	6.63	204	0.59	0.62	0.26	0.19	28.9	41	3	6	15	19

Appendix H3. Results of physico-chemical and microbiological analysis of groundwater samples collected between February and April, 2005

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*NO_3 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1KG001	2-Mar-05	Groundwater	6.86	18.9	-	-	-	0.04	0.03	82.2	7	0	0	0	0
1KG002	2-Mar-05	Groundwater	6.91	18.6	-	-	-	0.05	0.037	64.8	7	0	0	0	0
1KG003	2-Mar-05	Groundwater	6.8	18.3	-	-	-	0.03	0.022	82.9	37	0	0	0	5
1KG004	2-Mar-05	Groundwater	6.94	19.1	-	-	-	0.01	0.007	66	16	0	0	0	2
1KG005	1-Mar-05	Groundwater	6.54	17.2	-	-	-	0.04	0.03	42.2	67	0	0	5	11
1KG006	1-Mar-05	Groundwater	6.62	17.8	-	-	-	0.24	0.178	42	64	0	0	0	0
1KG007	24-Feb-05	Groundwater	6.72	15.7	-	-	-	0.28	0.208	71.9	50	0	0	0	0
1KG008	24-Feb-05	Groundwater	6.78	18.1	-	-	-	0.01	0.007	40.5	61	0	0	0	0
1KG009	24-Feb-05	Groundwater	6.72	18.3	-	-	-	0.71	0.528	119.6	160	0	0	9	44
1KG010	24-Feb-05	Groundwater	6.96	17.4	-	-	-	0.87	0.646	65.5	22	0	0	0	26
1KG011	15-Mar-05	Groundwater	6.81	18.8	-	-	-	0.09	0.067	26.4	7	0	0	0	0
1KG013	24-Feb-05	Groundwater	6.8	20.1	-	-	-	0.16	0.119	29.8	24	0	0	0	2
1KG015	10-Mar-05	Groundwater	6.85	14.2	-	-	-	0.2	0.149	61.4	190	0	0	8	141
1KG016	10-Mar-05	Groundwater	7.5	12	-	-	-	0.01	0.007	41	29	0	0	0	1
1KG017	9-Mar-05	Groundwater	6.8	17.6	-	-	-	0.09	0.067	84.8	24	0	0	0	0
1KG019	10-Mar-05	Groundwater	6.9	11.6	-	-	-	0.01	0.007	36.9	16	0	0	0	1
1KG020	10-Mar-05	Groundwater			-	-	-	0.07	0.052	40.6	8	0	0	0	0
1KG021	4-Mar-05	Groundwater	6.77	15.2	-	-	-	0.1	0.074	42.7	13	0	0	0	43
1KG022	4-Mar-05	Groundwater	6.77	14.1	-	-	-	0.2	0.149	29.2	23	0	0	0	2
1KG025	4-Mar-05	Groundwater	6.94	16.6	-	-	-	0.07	0.052	29.7	7	0	0	0	0
1KG026	4-Mar-05	Groundwater	6.91	17.1	-	-	-	0.08	0.059	24.7	7	0	0	0	11
1KG029	15-Mar-05	Groundwater	6.74	16.1	-	-	-	0.07	0.052	41.2	24	0	0	3	166
1KG030	15-Mar-05	Groundwater	6.83	16.6	-	-	-	0.13	0.097	46.6	23	0	0	105	128
1KG032	9-Mar-05	Groundwater	7.24	14.3	-	-	-	0.08	0.059	22.7	250	0	0	0	0
1KG034	9-Mar-05	Groundwater	6.92	17.4	-	-	-	0.16	0.119	54.6	19	0	0	0	0
1KG040	15-Mar-05	Groundwater	6.93	17.8	-	-	-	0.08	0.059	53.5	17	0	0	0	11
1KG044	16-Mar-05	Groundwater	6.96	18	-	-	-	0.13	0.097	14.4	7	0	0	0	0
1KG045	11-Mar-05	Groundwater	6.94	13.9	-	-	-	0.1	0.074	18.3	32	0	0	2	17

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*NO_3 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1KG046	11-Mar-05	Groundwater	6.87	14.9	-	-	-	0.01	0.007	6.1	130	0	0	0	1
1KG049	16-Mar-05	Groundwater	6.9	18.7	-	-	-	0.16	0.119	23.1	10	0	0	0	1
1KG051	16-Mar-05	Groundwater	6.84	18.3	-	-	-	0.13	0.097	21.5	7	0	0	0	0
1KG053	16-Mar-05	Groundwater	6.7	19.6	-	-	-	0.67	0.498	221	118	0	0	0	0
1KG054	1-Mar-05	Groundwater	6.48	16.1	-	-	-	0.08	0.059	111.4	76	0	0	1	3
1KG055	1-Mar-05	Groundwater	6.41	14.2	-	-	-	3.1	2.303	318	98	0	0	0	1
1KG056	1-Mar-05	Groundwater	6.81	18.3	-	-	-	0.12	0.089	21.2	8	0	0	1	2
1KG057	1-Mar-05	Groundwater	6.9	18.9	-	-	-	0.02	0.015	228	33	0	0	0	0
1KG058	2-Mar-05	Groundwater	6.57	18.9	-	-	-	0.01	0.007	107.2	21	0	0	0	0
1KG060	2-Mar-05	Groundwater	6.94	19.1	-	-	-	0.01	0.007	136.2	18	0	0	1	1
1KG061	3-Mar-05	Groundwater	7.15	17.4	-	-	-	0.07	0.052	47.5	19	0	0	0	22
1KG062	3-Mar-05	Groundwater	6.96	19	-	-	-	0.04	0.03	14.4	7	0	0	0	3
1KG063	3-Mar-05	Groundwater	7	18.4	-	-	-	0.03	0.022	55.8	28	0	0	0	14
1KG064	3-Mar-05	Groundwater	7.27	19.5	-	-	-	0.03	0.022	17.1	7	0	0	0	2
1KG065	3-Mar-05	Groundwater	6.92	18.5	-	-	-	0.04	0.03	53.2	7	0	0	0	1
1KG069	25-Feb-05	Groundwater	7.04	17.4	-	-	-	0.01	0.007	48.3	16	0	0	69	75
1KG070	25-Feb-05	Groundwater	6.96	19	-	-	-	0.04	0.03	30.7	7	0	0	0	0
1KG071	25-Feb-05	Groundwater	6.86	19.6	-	-	-	0.03	0.022	60.4	7	0	0	0	0
1KG072	25-Feb-05	Groundwater	6.88	18.9	-	-	-	0.03	0.022	68.9	19	0	0	6	6
1KG073	25-Feb-05	Groundwater	6.81	16.9	-	-	-	0.02	0.015	70	15	0	0	2	2
1KG074	3-Mar-05	Groundwater	6.52	19.2	-	-	-	0.01	0.007	14.5	25	0	0	0	0
1KG075	1-Mar-05	Groundwater	6.82	17.7	-	-	-	0.15	0.111	82.1	7	0	0	0	0
1KG076	4-Mar-05	Groundwater	6.61	14.8	-	-	-	0.22	0.163	26.7	7	0	0	0	7
1KG077	9-Mar-05	Groundwater	7	14.6	-	-	-	0.08	0.059	9.2	124	0	0	0	0
1KG078	9-Mar-05	Groundwater	7.1	17.3	-	-	-	0.09	0.067	1	170	0	0	0	22
1KG079	11-Mar-05	Groundwater	6.92	16.3	-	-	-	0.02	0.015	23.4	17	0	0	0	1
1KG080	11-Mar-05	Groundwater	6.63	15.2	-	-	-	0.02	0.015	173	35	0	0	0	2
1KG081	11-Mar-05	Groundwater	6.85	16.9	-	-	-	0.09	0.067	47.5	13	0	0	0	1
1KG082	11-Mar-05	Groundwater	6.62	17.1	-	-	-	0.06	0.045	101	34	0	0	1	255

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp* °C	*DO* *(mg/L)*	*TDS* *(mg/L)*	*NH_3* *(mg/L)*	*PO_4* *(mg/L)*	*P_2O_5* *(mg/L)*	*NO_3* *(mg/L)*	*SO_4* *(mg/L)*	*BOD* *(mg/L)*	*COD* *(mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1KG083	15-Mar-05	Groundwater	6.79	18.9	-	-	-	0.06	0.045	48.5	24	0	0	2	2
1KG084	15-Mar-05	Groundwater	6.95	19	-	-	-	0.08	0.059	29.9	7	0	0	0	1
1KG085	16-Mar-05	Groundwater	6.82	19.2	-	-	-	0.03	0.022	26.1	20	0	0	0	0

Appendix H4. Results of physico-chemical and microbiological analysis of samples from industrial and domestic wastewater effluents collected between February and April, 2005

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*NO_3 (mg/L)*	*SO_4 (mg/L)*	*BOD_5 (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1WF089	21-Mar-05	IWW	7.51	23.3	5.8	444	0.06	0.39	0.29	12.3	180	470	1,848	24500	32500
1WF089	24-Mar-05	IWW	7.32	20.1	7.32	344	0.05	0.04	0.03	4.9	140	298	596	6500	7500
1WF182	11-Mar-05	IWW	7.82	17	6.27	494	5	9.1	6.761	100	7	222	2620	18000	32000
1WR044	21-Mar-05	IWW	7.41	29.7	4.55	578	0.1	0.11	0.082	5.7	240	515	859	176000	180000
1WR065	21-Mar-05	IWW	7.06	21.6	6.05	354	0.62	0.15	0.111	1	7	776	1,332	244000	250000
1WR163	16-Mar-05	IWW	7.1	17.5	5.92	474	19	30.8	22.88	390	24	1802	1836	740000	740000
1WR164	16-Mar-05	IWW	7.39	14.4	4.52	528	17	29.4	21.84	82.1	60	287	456	260000	260000
1WR211	11-Mar-05	IWW	7.22	10.2	7.96	407	21	6.9	5.127	71.4	33	78	171	18000	32000
1WR228	18-Mar-05	IWW	9.31	18.8	5.53	871	0.68	27.6	20.51	8.6	270	133	196	262	300
1WR042	7-Apr-05	DWW				504	0.19	0.08	0.059	17.7	140	523	792	450000	450000
1WR055	7-Apr-05	DWW				270	28	1.85	1.375	31.8	10	281	474	600000	600000
1WR060	7-Apr-05	DWW				214	8	2.7	2.006	4.4	38	24.8	34	146000	150000
1WR069a	23-Mar-05	DWW	9.53	13	6.71	1,110	17	22	16.35	10.8	7	969	1,216	220000	220000
1WR069b	23-Mar-05	DWW	7.37	12	5.69	249	7	1.71	1.271	13	30	31	35	52000	55000
1WR107	24-Mar-05	DWW	7.4	14.1	2.4	322	29.5	7.1	5.275	29.9	35	112	152	850000	850000
1WR108	24-Mar-05	DWW	7.47	15.6	2.16	360	56	13.6	10.1	21.4	39	183.5	291	900000	900000
1WR109	11-Mar-05	DWW	7.42	10.4	5.7	369	34	15.4	11.44	7.7	33	165	326	18000	32000
1WR112	18-Mar-05	DWW	7.69	17.2	1.48	612	88	24.6	18.28	12.8	40	340	474	1250000	1250000
1WR128	16-Mar-05	DWW	7.94	14.7	4.8	549	55	29.8	22.14	27.6	95	369	710	280000	280000
1WR130	16-Mar-05	DWW	7.3	15.5	5.21	444	23	11.4	8.47	35.5	60	185	379	340000	340000
1WR132	16-Mar-05	DWW	6.7	15.7	4.7	1960	14	25.4	18.87	15.6	105	777	1200	220000	220000
1WR134	16-Mar-05	DWW	7.26	15.2	3.16	494	40	22.4	16.64	56.4	65	210	445	400000	400000
1WR145	17-Mar-05	DWW	7.81	14.2	6.81	925	152	30	22.29	39.4	7	349	865	3500	16500
1WR154	4-Apr-05	DWW				349	55.5	16.1	11.96	28.6	9	238	382	600000	600000
1WR157	11-Mar-05	DWW	7.12	12.3	3.66	365	10	16.1	11.96	10.9	45	143	260	18000	32000

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*PO_4 (mg/L)*	*P_2O_5 (mg/L)*	*NO_3 (mg/L)*	*SO_4 (mg/L)*	*BOD_5 (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
1WR162	16-Mar-05	DWW	7.46	12.9	3.35	454	27	7.3	5.424	29	59	93	204	340000	340000
1WR171	11-Mar-05	DWW	7.19	12.2	1.9	348	3.8	0.32	0.238	6.8	48	64	281	18000	32000
1WR173	9-Mar-05	DWW	7.41	16.3	3.11	409	62	24.4	18.13	23.7	7	204	367	220000	220000
1WR219	17-Mar-05	DWW	7.66	13.1	2.31	464	37	10.7	7.95	32.8	37	184	306	1000000	1000000

Appendix H5. Results of physico-chemical and microbiological analysis of samples from Canal 900

Sample ID	*Date sample received*	*Matrix*	*pH*	*Temp*	*DO*	*TDS*	*NH_3*	*o-PO_4^{3-}*	*NO_3^-*	*SO_4^{2-}*	*BOD*	*COD*	*FC*	*TC*
1WC001	18-April-05	Canal	7.61	12.9	3.20	257	0.46	0.55	20.9	39	<2	<2	45	58 CFU/2ml
1WC002	18-April-05	Canal	7.20	13.1	3.37	238	0.47	0.52	17.7	38	<2	<2	8	150
1WC003	18-April-05	Canal	7.12	13.7	3.95	245	0.43	0.46	25.1	36	<2	<2	0	38
1WC004	18-April-05	Canal	7.07	14.1	4.22	241	0.35	0.35	19.9	36	<2	<2	0	12
1WC005	18-April-05	Canal	7.18	15.6	4.12	251	0.44	0.40	18.8	34	<2	<2	3	13 CFU/2ml
1WC006	18-April-05	Canal	7.33	17.5	9.27	242	0.41	0.26	16.8	35	<2	3	22	14 CFU/2ml
1WC007	18-April-05	Canal	7.48	17.4	11.54	235	0.45	0.47	22.0	38	5.6	7	≈600	11 CFU/2ml
1WC008	18-April-05	Canal	7.58	13.9	12.93	236	0.29	0.27	21.2	36	<2	5	11	7 CFU/2ml
1WC009	18-April-05	Canal	7.53	18.4	12.23	231	0.22	0.23	23.9	32	<2	<2	4	62
1WC010	18-April-05	Canal	7.94	18.8	13.71	236	0.13	0.19	21.6	36	<2	7	25	70
1WC011	18-April-05	Canal	7.99	19.1	15.44	226	0.11	0.08	21.7	37	<2	3	0	7 CFU/2ml
1WC012	18-April-05	Canal	7.92	19.7	14.47	231	0.12	0.13	22.5	38	<2	4	216	23 CFU/2ml
1WC013	18-April-05	Canal	7.48	19.2	9.41	247	0.23	0.11	20.9	38	<2	3	15	31 CFU/2ml
1WC014	18-April-05	Canal	7.64	21.2	12.67	222	0.32	0.01	18.6	44	3.7	15	0	40

Appendix H6. Results of analysis on fish samples

Fish	*Length (cm)*	*Weight (g)*	*Chromium (mg/Kg)*	*Cadmium (mg/Kg)*	*Lead (mg/Kg)*
1	25 cm	150 g	0.035155	0.10668	0.013373
2	27 cm	183 g	0.059815	8.012442	0.081379
3	26 cm	155 g	0.06301	0.140257	0.112398
4	26.8 cm	165 g	0.040231	0.030114	0.009494
5	25.5 cm	134 g	0.035907	70.157	0.026734
6	43 cm	759.85 g	0.045416	0.172534	0.006497
7	26 cm	155 g	0.078155	0.670346	1.84274
PARTS OF FISH					
8	Gills Composite sample from Fish # 6 and 7		0.12527	0.378941	0.085923
9	Fish # 7		0.053411	0.10094	0.088556
Method Detection Limit			0.002	0.002	0.002

Appendix H7. Results of analysis on heavy metals in water samples

Sample ID	*Matrix*	*Pb (mg/L)*	*Hg (mg/L)*	*Cd (mg/L)*	*Cr (mg/L)*	*Ni (mg/L)*	*Cu (mg/L)*	*Zn (mg/L)*
1KG003	Groundwater	<MDL	<MDL	<MDL	<MDL	0.00427	0.0046	0.01378
1KG004	Groundwater	<MDL	<MDL	<MDL	<MDL	0.00251	<MDL	<MDL
1KG005	Groundwater	<MDL	<MDL	<MDL	<MDL	0.00217	<MDL	0.01947
1KG006	Groundwater	<MDL	<MDL	<MDL	0.0030	0.0041	<MDL	0.0036
1KG007	Groundwater	<MDL	<MDL	<MDL	<MDL	0.0035	<MDL	0.01349
1KG008	Groundwater	<MDL	<MDL	<MDL	<MDL	0.003	<MDL	0.00409
1KG009	Groundwater	<MDL	<MDL	<MDL	<MDL	0.004	<MDL	0.00699
1KG010	Groundwater	<MDL	<MDL	<MDL	<MDL	0.002	0.002	0.00679
1KG013	Groundwater	<MDL	<MDL	<MDL	0.0032	0.0039	0.002	0.00369
1KG015	Groundwater	0.0021	<MDL	<MDL	<MDL	0.00420	<MDL	0.0832
1KG016	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.6098
1KG019	Groundwater	0.0075	<MDL	<MDL	<MDL	0.0028	0.0086	0.9363
1KG020	Groundwater	<MDL	<MDL	<MDL	0.002108	0.0059	<MDL	1.1295
1KG022	Groundwater	0.0044	<MDL	<MDL	<MDL	0.0131	0.009	8.833
1KG026	Groundwater	<MDL	<MDL	<MDL	<MDL	0.0023	<MDL	0.02081
1KG029	Groundwater	<MDL	<MDL	<MDL	<MDL	0.002734	<MDL	4
1KG044	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	0.00274	0.00731
1KG045	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.3074
1KG049	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.007
1KG053	Groundwater	<MDL	<MDL	<MDL	<MDL	0.022115	<MDL	2.4
1KG055	Groundwater	<MDL	<MDL	<MDL	0.0022	0.0041	<MDL	0.0056
1KG057	Groundwater	<MDL	<MDL	<MDL	0.0020	0.0029	<MDL	0.3699
1KG058	Groundwater	<MDL	<MDL	<MDL	<MDL	0.0022	<MDL	0.02147
1KG065	Groundwater	<MDL	<MDL	<MDL	<MDL	0.00207	<MDL	<MDL
1KG069	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.00739
1KG074	Groundwater	<MDL	<MDL	<MDL	<MDL	0.00697	<MDL	0.0021
1KG075	Groundwater	<MDL	<MDL	<MDL	0.0023	0.0028	0.0022	0.1455
1KG079	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG081	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.09029
1KG083	Groundwater	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	0.02453
1WR004	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR019	Waste Water	0.00411	<MDL	0.002	<MDL	-	-	-
1WR024	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR027	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR036	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR044	Industrial waste	0.0037	<MDL	<MDL	0.0056	-	-	-
1WR052	River	0.00600	<MDL	<MDL	<MDL	-	-	-
1WR065	Industrial waste	0.0035	<MDL	<MDL	0.0020	-	-	-
1WR089	Industrial waste	0.0081	<MDL	0.0020	0.0046	-	-	-
1WR109	Waste Water	0.01	<MDL	<MDL	<MDL	-	-	-
1WR111	Run Off	0.0043	<MDL	<MDL	0.0020	-	-	-
1WR112	Waste Water	0.0035	<MDL	<MDL	0.0020	-	-	-
1WR113	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR128	Waste Water	0.0086	<MDL	<MDL	0.0022	-	-	-
1WR130	Waste Water	0.0071	<MDL	<MDL	0.0020	-	-	-
1WR132	Waste Water	0.0023	<MDL	<MDL	0.0049	-	-	-
1WR134	Waste Water	0.0034	<MDL	<MDL	0.0020	-	-	-

Sample ID	*Matrix*	*Pb (mg/L)*	*Hg (mg/L)*	*Cd (mg/L)*	*Cr (mg/L)*	*Ni (mg/L)*	*Cu (mg/L)*	*Zn (mg/L)*
1WR135	Waste Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR145	cow manure+spring water	0.0043	<MDL	<MDL	0.0029	-	-	-
1WR150	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR157	Waste Water	0.004	<MDL	<MDL	<MDL	-	-	-
1WR159	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR162	Waste Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR163	Industrial waste water	<MDL	<MDL	<MDL	0.0068	-	-	-
1WR164	Industrial waste water	<MDL	<MDL	<MDL	0.0044	-	-	-
1WR171	Waste Water	0.0033	<MDL	<MDL	<MDL	-	-	-
1WR173	Waste Water	0.00296	<MDL	0.002143	<MDL	-	-	-
1WR182	Industrial waste water	0.0022	<MDL	<MDL	0.0029	-	-	-
1WR184(b)	Lake Water	0.0026	<MDL	<MDL	<MDL	-	-	-
1WR185(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR186(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR187(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR188(b)	Lake Water	0.0030	<MDL	<MDL	<MDL	-	-	-
1WR189(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR190(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR191(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR192(b)	Lake Water	0.002	<MDL	<MDL	<MDL	-	-	-
1WR193(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR194(b)	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR195	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR196	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR196	Sediment Bag	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR197	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR198	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR199	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR200	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR201	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR202	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR203	Lake Water	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR205	River	0.00321	<MDL	<MDL	<MDL	-	-	-
1WR208	River	0.0041	<MDL	<MDL	<MDL	-	-	-
1WR211	Industrial waste water	<MDL	<MDL	<MDL	0.0022	-	-	-
1WR215	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR219	Waste water	0.0022	<MDL	<MDL	<MDL	-	-	-
1WR225	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR225	River	<MDL	<MDL	<MDL	<MDL	-	-	-
1WR228	Industrial waste	<MDL	<MDL	<MDL	<MDL	-	-	-
C900 (IN)	Surface water	<MDL	<MDL	<MDL	<MDL	0.0027	<MDL	0.00689

Appendix H8. Results of analysis on heavy metals on soil and sediment samples

Type	*Code*	*Lead Pb mg/Kg*	*cadmium Cd mg/Kg*	*Chromium Cr mg/Kg*	*PhosphateFinal mg/Kg*	*Ammonia-N mg/Kg*	*Total nitrogen %*	*Total Carbon %*
Soil	1WO001	16.61	1.51	84.15	47.4	93.04	0.0969	3.688
	1WO002	21.25	1.42	282.21	62.25	23	0.094	1.233
	1WO003	25.25	4.38	122.51	130	42.5	0.063	0.513
	1WO004	17.14	2.04	254.37	140	9.25	0.111	1.116
	1WO005	17.56	2.87	145.35	61.5	13.5	0.286	2.609
	1WO006	15.52	0.81	69.64	55.7	8.5	0.092	4.09
	1WO007	19.19	0.97	159.7	94.9	11.75	0.102	2.381
	1WO008	25.33	2.89	301.98	119.625	21	0.107	1.394
	1WO009	20.61	1.15	236.79	67.5	27.2	0.09	2.748
	1WO010	20.06	1.13	250.75	60	42.3	0.084	1.903
	1WO011	29.44	2.15	202.48	97	40.425	0.0677	1.0384
	1WO012	22.86	1.95	179.59	118.125	15.175	0.291	2.672
	1WO013	19.47	5.16	171.95	174.575	15.125	0.071	0.722
	1WO014	21.18	1.18	182.85	101.25	9.95	0.047	3.906
	1WO015	27.65	5.02	226.57	265.9	7.925	0.108	1.052
	1WO016	11.101	<0.002	16.574	43.75	49.75	0.058	2.147
	1WO017	9.787	<0.002	13.363	65.25	9.775	0.06354	3.358
	1WO018	10.855	<0.002	16.461	69.75	53.55	0.064	3.01
	1WO019	8.54	<0.002	14.113	78	23.525	0.08673	5.381
	1WO020	9.274	<0.002	15.025	-	110.8	0.0839	4.637
Sediment	1WR196	<0.002	<0.002	<0.002	135mg/L	Interference turbidity		
	1WR254	31.285	3.391	633.35	117.5	248.72	NR	NR

Type	*Code*	*Lead Pb mg/Kg*	*cadmium Cd mg/Kg*	*Chromium Cr mg/Kg*	*PhosphateFinal mg/Kg*	*Ammonia-N mg/Kg*	*Total nitrogen %*	*Total Carbon %*
	1WR255	24.5	3.47	486.215	115.25	132.16	NR	NR
	1WR256	19.758	2.112	319.705	127.375	164.16	NR	NR
	1WR257	25.613	3.277	570.175	91.125	0	NR	NR
	1WR258	34.053	2.042	487.468	32.875	65.6	NR	NR
	1WR259	27.95	0.866	345.394	143.5	164	NR	NR
	1WR260	33.176	2.269	452.16	100.875	99.44	NR	NR
	1WR261	32.383	1.246	348.611	144	277.6	NR	NR
	1WR262	38	2.497	458.839	187.25	205.6	NR	NR

Appendix H9. Results of analysis on pesticides on groundwater samples

Sample ID	*Triethyl phosphorothioate*	*Thionazin (Zinophos)*	*Sulfotep*	*Phorate*	*Dimethoate*	*Disulfoton*	*Methyl parathion*	*Parathion*	*Famphur*	*Alpha-BHC*	*Gamma-BHC (Lindane)*	*Beta-BHC*
1KG003	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG004	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG005	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG006	<MDL	<MDL	<MDL	<MDL	<MDL	0.048 ppb	<MDL	0.011 ppb	<MDL	<MDL	<MDL	<MDL
1KG007	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG008	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG009	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG010	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG013	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG015	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG016	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG019	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG020	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG022	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG026	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG029	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG044	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG045	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG049	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	X	<MDL	<MDL	<MDL
1KG053	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	X	<MDL	<MDL	<MDL
1KG055	<MDL	<MDL	<MDL	<MDL	<MDL	0.463 ppb	<MDL	0.118ppb	<MDL	<MDL	<MDL	<MDL
1KG057	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG058	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG065	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG069	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG074	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG075	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG079	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL

Sample ID	*Triethyl phosphorothioate*	*Thionazin (Zinophos)*	*Sulfotep*	*Phorate*	*Dimethoate*	*Disulfoton*	*Methyl parathion*	*Parathion*	*Famphur*	*Alpha-BHC*	*Gamma-BHC (Lindane)*	*Beta-BHC*
1KG081	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
1KG083	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL

Appendix I. Form of health survey of public clinics

1. **Name of the interviewer:** ____________________________________
2. **Date of the interview:** ____________________________________

---

3. **Name and location of the surveyed public clinic:** ____________________________________

   3.1. Name of the doctor (or person in charge): ____________________________________

   3.2. Phone number: ____________________________________

4. **Number of diarrhea cases recorded in the medical facility between January 2004 and January 2005:** ____________________

   4.1. Treatment cost of one diarrhea case (in Lebanese pound) ____________________

   Medication______________ Hospital stay_____________ Transportation_____________

5. **Number of typhoid cases recorded in the medical facility between January 2004 and January 2005:** ____________________

   5.1. Treatment cost of one typhoid case (in Lebanese pound): ____________________

   Medication______________ Hospital stay_____________ Transportation_____________

6. **The number of diarrhea and typhoid cases recorded in the surveyed medical facility between January 2004 and January 2005 may be considered:**

   ☐ Below the average annual number of cases for the last 5 years

   ☐ Above the average annual number of cases for the last 5 years

   ☐ More or less equal to the average annual number of cases for the last 5 years

   6.1 In case of <u>below</u> or <u>above</u> the annual average, what are the possible reasons?

   1. ____
   2. ____

General Remarks

____

____

____

____

____

Appendix J. Form of farmers survey along Canal 900

1. **Name of the interviewer:** ____________________
2. **Date of the interview:** ____________________

---

3. **Name of the surveyed village:** ____________________
4. **Name of the interviewed farmer:** ____________________
5. **How many dunums did you cultivate in the last agricultural year (October 2003-September 2004)?**

   ____

5.1. How many **dunums** are irrigated from Canal 900? ____________

5.2. How many **dunums** are irrigated from artesian wells? ____________

5.2.1. Why are you using artesian wells for irrigation?
1.____________________
2.____________________

6. **What are the main problems you are facing from the use of Canal 900?**

1.____________________
2.____________________

7. **Do you or did you have damages to the irrigation network because of water quality in Canal 900**

☐ **Yes** ☐**No**

7.1 If yes, how much is your total damage cost <u>per year</u> (in LBP)? ____________

8. **Have you installed a filter to the irrigation network?** ☐ **Yes** ☐ **No**

8.1. If yes, what type of filter? ____________________

8.1.1. How much did you pay for the filter? ____________(in LBP)

8.1.2. How much time do you spend per irrigation season to clean the filter? ________(in hours)

8.1.3 If hired labor is used to clean the filter, how much do you pay per irrigation season? ________ (in LBP)

9. **How much do you pay for the Litani Authority <u>per dunum</u> per year for the use of Canal 900?**

   ____________ **(in LBP)**

10. **How much is your total irrigation cost <u>per year</u> resulting from the use of artesian wells?**

    ____________ **(in LBP)**

11. **How much are you willing to pay for the Litani Authority <u>per dunum</u> per year for the use of Canal 900, if water with good quality for irrigation can be provided?**

    ____________ **(in LBP)**

General Remarks

____

____

____

Appendix K. At Farm Level Agricultural Questionnaire

LWQM

Questionnaire no. _____

ON-FARM AGROCHEMICAL USE/IRRIGATION PRACTICES INTERVIEW QUESTIONNAIRE

Respondent Data

1. Interview Date *(day/month/year)*	______________________
2. Enumerator Name	______________________
3. Respondent Name	______________________
4. Telephone No. (*ask at end of interview*)	______________________
5. Respondent's relationship to Farm Unit	1. ☐ Owner/Farmer 2. ☐ Manager/ Foreman 3. ☐ Other ______________
6. Farm Coordinates	North:________ East:__________

General Farming Data

7. Land Status	1. ☐ Owned 2. ☐ Leased ____________ season ____________ months		
8. Farm Area (dunums)			
9. Irrigated Area (dunums)			
10. Crop Production Type *(check all that apply)*	1. ☐ Orchards 2. ☐ Vineyard 3. ☐ Vegetables 4. ☐ Field crops (potato, cereal, forage, sugar beet, etc.) 5. ☐ Other ______________		
11. Cropping rotation	Crop	From	To
12. Source of Irrigation Water *(check all that apply)*	1. ☐ Surface Water 2. ☐ Groundwater 3. ☐ Both		
13. Type of Irrigation System *(check all that apply)*	1. ☐ Drip 2. ☐ Sprinkler 3. ☐ Rain Gun	4. ☐ Surface – Flood 5. ☐ Surface – Furrow 6. ☐ Other ______________	
14. If Drip, Do you use filters?	1. ☐ Yes 2. ☐ No		
15. If Drip, Do you clean emitters?	1. ☐ Yes 2. ☐ No		
16. What is the major problem affecting production on your	1. ☐ Fertility 2. ☐ Pests	3. ☐ Poor Drainage 4. ☐ Other	

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Questionnaire no. ______

farm?	

Agrochemical Chemical Use Information Sources and Attitudes

17. Do you fertigate?	1. ☐ Yes 2. ☐ No
18. If no, how do you apply the fertilizers	______
19. Do you receive technical assistance to improve fertilizer and pesticide use?	1. ☐ Yes 2. ☐ No
20. If yes, from where do you get the information?	1. ☐ Ministry of Agriculture 2. ☐ Other Governmental Agency ______ 3. ☐ University 4. ☐ Suppliers 5. ☐ Farmer Cooperative 6. ☐ Other Farmers 7. ☐ Other ______
21. Do you need technical information to improve fertilizers/Pesticide use efficiency?	1. ☐ Yes 2. ☐ No
22. If yes, from what source would you prefer to get technical information?	1. ☐ Government Extension Services 2. ☐ University 3. ☐ Suppliers 4. ☐ Farmer Cooperative 5. ☐ Other Farmers 6. ☐ Other ______

Observations: (Note any observations that you think will be relevant for analyzing the data collected.)

______

______

______

______

______

Questionnaire no. _____

Crops Grown from October 2003 to September 2004

Cultivated Crop	Period		Cultivated Area (Dunums)	Type of Irrigation
	From	To		
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow
				1. ☐ None 2. ☐ Drip 3. ☐ Sprinkler 4. ☐ Rain Gun 5. ☐ Surface - Flood 6. ☐ Surface - Furrow

Questionnaire no. _____

Agricultural Chemical Use, (October 2003- September 2004)

Crop: ______________________

Fertilizers (Be as precise as possible. For type, include type of manure [cow, chicken, etc.] N-P-K values for the product used. For amount, collect sufficient data to convert amount into kg/dunum [if reported in bags, determine size of bags, if reported as truck loads, get estimate of truck volume, etc.])

First Application			Second Application			Third Application			Fourth Application		
Timing	Type/ Name	Amount	Timing	Type/ Name	Amount	Timing	Type/ Name	Amount	Timing	Type/ Name	Amount

Pesticides (Be as precise as possible. If you cannot get a commercial name, get at least the local common name and write a description. For dose, collect sufficient data to convert dose into kg/dunum [if reported in bags, determine number of bags per dunum and size of bags, if reported as a solution, determine liter of pesticide to liter of water as well as liters of solution per dunum, etc.])

Commercial Name	Pest	Application		Dose
		Number	Timing	

4

Appendix L. Agenda of the first meeting of the National Working Group

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مشروع إدارة نوعيّة المياه في حوض الليطاني

برنامج الإجتماع التأسيسي لفريق العمل الوطني

الزمان: الأربعاء الواقع في ٢٠ نيسان، ٢٠٠٥

المكان: فندق بارك أوتيل (Park Hotel)، شتورة

٩:١٥	تسجيل المشتركين	
٩:٣٠	كلمة ترحيب	مارك سعادة حسين رمال
٩:٣٥	مقدّمة عامة	رامي زريق
٩:٤٥	لمحة حول نشاطات وإنجازات مشروع إدارة نوعية المياه في حوض الليطاني الإنجازات في مجال المسح التقني لنوعيّة المياه السطحيّة الإنجازات في مجال المسح التقني لنوعيّة المياه الجوفيّة	مارك سعادة معتصم الفاضل عادل أبو جوده
١٠:٢٠	أهميّة النواحي القانونيّة والمؤسساتيّة في وضع الخيارات لإدارة نوعيّة المياه	جان كرم
١٠:٣٠	عرض للوثيقة المحدّدة لدور ومهام فريق العمل الوطني	
١١:٠٠	إستراحة	
١١:١٠	تحضير لورشة العمل الثانية للمشروع	
١٢:١٠	مناقشة عامة	
١٢:٣٠	غداء	

DAI In collaboration with WESS

Litani Water Quality Management Project (BAMAS)
Litani River Authority Offices, Bechara el Khoury, Beirut, Lebanon
Tel/Fax: +٩٦١ ١ ٦٦٢ ١١٧

Appendix M. Roles and responsibilities of the National Working Group

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مشروع إدارة نوعية المياه
في حوض الليطاني

LWQM

دور ومسؤوليات
فريق العمل الوطني

تاريخ التأسيس: ٢٠/نيسان/٢٠٠٥

DAI in collaboration with WESS

Litani Water Quality Management Project (BAMAS)
Litani River Authority Offices, Bechara el Khoury, Beirut, Lebanon
Tel/Fax: +٩٦١ ١ ٦٦٤ ١١٧

مقدّمة عامّة

تنتج مشكلة تلوّث المياه في الحوض الأعلى لنهر الليطاني وبحيرة القرعون عن عدّة عوامل أهمّها عدم معالجة المياه المبتذلة، والرمي العشوائي للنفايات الصلبة والمخلفات الصناعيةً والكيماويّات الزراعيّة. كل هذه العوامل تنعكس بشكل خاص على كافة استعمالات المياه، كما تنتج عنها تأثيرات تضرّ بالصحة العامة وبالوضعين الإجتماعي والإقتصادي في المنطقة. لذلك، تستدعي هذه المشكلة إيجاد حلول قائمة على أسس الإدارة المستدامة لنوعيّة المياه السطحيّة والجوفيّة في هذا الحوض.

بالنظر إلى هذا الواقع، وقّعت المصلحة الوطنيّة لنهر الليطاني بتاريخ ١٦ كانون الأوّل ٢٠٠٤ مذكّرة تفاهم مع بعثة الوكالة الأميركيّة للتنمية الدوليّة (USAID) في لبنان، من أجل تنفيذ برنامج دعم فنّي لتحسين إدارة نوعيّة المياه في الحوض الأعلى لنهر الليطاني (Litani Water Quality Management LWQM) من خلال شركة DAI الأميركيّة بالتعاون مع شركتي WESS وخطيب وعلمي اللبنانيّتين.

بناءً على معطيات علميّة وعمليّة وعبر إشراك المعنيّين في كافة نشاطاته، يهدف هذا المشروع المموّل من قبل الوكالة الأميركيّة للتنمية الدوليّة الى تحديد الخيارات المتاحة لإدارة وتحسين نوعيّة المياه في الحوض الأعلى لنهر الليطاني وبحيرة القرعون، ووضع مخطّط بيئي للمنطقة يتم من خلاله تطبيق هذه الخيارات على الأرض. وضمن هذا الإطار، فإن أهم نتائج المشروع المرتقبة هي ١) تحديد الخيارات والاستثمارات المطلوبة لمعالجة تلوّث المياه وإدارة نوعيّتها في المنطقة، ٢) وضع خطط عمل جاهزة للتنفيذ، لتطبيق هذه الخيارات والسيناريوهات من قبل المعنيّين و/أو المموّلين، و٣) تشكيل فريق عمل وطني يساهم في تحديد الخيارات ويتابع تطبيق خطط العمل.

تعرض الوثيقة المرفقة دور ومسؤوليّات فريق العمل الوطني بالإضافة إلى آليّة عمله.

دور ومسؤوليّات فريق العمل الوطني

١. يتكوّن فريق العمل الوطني من ممثلين لمختلف الجهات التي تتأثر وتؤثر بشكل مباشر على نوعية مياه الحوض الأعلى لنهر الليطاني. ويتألف أعضاء فريق العمل الوطني من الجهات الممثّلة بالأشخاص التالية أسماؤهم، و كانت أغلبيتهم قد أبدت رغبتها بالمشاركة:

أعضاء فريق العمل الوطني

الجهة	الممثل	الجهة	الممثل
مصلحة مياه نهر الليطاني	حسين رمال	بلدية زحلة	إبراهيم ابو ديب
مؤسسة مياه البقاع	محمد شوباصي	بلدية تعنايل	عساف صوايا
مجلس الإنماء والإعمار	زهير الحسن	بلدية بدنايل	يوسف سليمان
وزارة الطاقة والمياه	حسن جعفر	غرفة التجارة والزراعة والصناعة- زحلة	سعيد جدعون
وزارة البيئة	أسعد سعادة	جمعية الصناعيين	محي الدين نخلاوي
وزارة الزراعة	حسين نصرالله	معمل الشمندر السكري	أنطوان نهرا
وزارة الصناعة	ربيع صعب	المزارعون/ التعاونيّات الزراعيّة	صفا عيسى
إتحاد بلديات السهل	جورج خوري	مجلس الثقافي والإجتماعي للبقاع وراشيا	عمر كنعان
إتحاد بلديات البحيرة	ربيع جمعة	أكاديميا	سليم مقصود

٢. يلعب فريق العمل الوطني دوراً حيويّاً في المشروع ويتولى الفريق المسؤوليات التالية:

- مواكبة نشاطات المشروع
- المساهمة في وضع الخيارات لمعالجة المياه وإدارة نوعيتها بما يتناسب مع أهداف وإستراتيجية المشروع
- التواصل والتنسيق مع الجهات المعنية لنقل آرائها وتطلّعاتها ولإطلاعها على سير عمل المشروع وأهم نتائجه
- متابعة تطبيق خطة العمل المنبثقة عن المشروع

٣. يتمّ تحقيق أهداف فريق العمل الوطني من خلال:

أ. إجتماعات عامة دورية للفريق تعقد مرة كل ستة أسابيع وتتضمن عرضاً لإنجازات المشروع، ومناقشة عامة للمواضيع التي هي قيد الدرس، وتحضيراً لورشات العمل المبرمجة من قبل المشروع.

ب. إجتماعات للجان مصغرّة مختصة بالمواضيع المطروحة تتشكل من قبل المعنيين مباشرةً بالمواضيع التي هي قيد الدرس بحيث يتمّ عرض هذه المواضيع ومناقشة النواحي التقنية والمؤساستية والقانونية منها مع إستشاريّي المشروع.

ج. إجتماعات خاصة إستثنائية تعقد وفقاً لمتطلبات المشروع بناءً على طلب خاص من قبل مدير المشروع أو بناءً على طلب خاص من قبل أعضاء يمثلون ثلث أعضاء فريق العمل الوطني على الأقل.

٤. تقوم إدارة المشروع، خلال فترة تطبيقه، بتنسيق النشاطات وإدارة الجلسات، كما تقوم بإعداد التقارير عن الجلسات وتوزيعها لأعضاء فريق العمل الوطني.

٥. يقوم فريق العمل الوطني بمناقشة المواضيع ذات الصلة التي تطرحها عليه إدارة المشروع ومن بين أهمّها، على سبيل المثال لا الحصر:

أ. المسؤوليات المؤسساتية في تطبيق برنامج دوري لرصد نوعية مياه الحوض الأعلى لليطاني
ب. الخيارات المتعلقة بإدارة عملية جمع ومعالجة المياه المبتذلة
ج. الخيارات المتعلقة بإدارة المخلفات الصناعية
د. الخيارات المتعلقة بإدارة النفايات المنزلية الصلبة
ه. الخيارات المتعلقة بإدارة مصادر التلوث الناتج عن الكيماويات الزراعية (أسمدة ومبيدات)
و. النواحي القانونية لخيارات إدارة نوعية مياه الليطاني
ز. مسودة خطة العمل المنبثقة عن مشروع إدارة نوعية مياه الليطاني
ح. المسؤوليات لتطبيق خطة العمل المنبثقة عن مشروع إدارة نوعية مياه الليطاني.

Appendix N. Agenda of the Second Workshop

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LWQM

LITANI WATER QUALITY MANAGEMENT (BAMAS)
TECHNICAL SURVEY WORKSHOP PROGRAM

Date: Wednesday, June 1, 2005
Location: Chtaura Park Hotel, Bekaa

09:00	Registration with Coffee	
	Opening Ceremony	
09:30	Opening Note by LWQM Project Manager	Mark Saadeh
09:35	Opening Note by Director of USAID mission in Lebanon	Raouf Youssef
09:45	Opening Note by Director General of Litani River Authority	Ali Abboud
09:55	BAMAS Project Overview/ Accomplishments	Rania Maroun
	Technical Survey Findings and Recommendations	
10:05	Surface and Groundwater Quality Sampling Results and Recommendations	Mutasem El Fadel Adel Abou Jaoude
10:30	Planned Waste Water Treatment Plants and O&M Concerns	Adel Abou Jaoude Roger Melki
10:45	Agricultural & Health Survey Results	Dany Lichaa Mutasem El Fadel
11:00	Algae Control of Canal 900	Mohamed Chebaane
11:10	Questions/Discussion	
11:45	Coffee Break	
12:15	Long Term Water Quality Monitoring	Mark Saadeh
12:25	Roles and Responsibilities of NWG	Omar Kanaan
12:40	Summary of Recommendations related to Litani Basin Water Quality Management	Mohamed Chebaane
12:45	Collaborative Planning and Legal and Institutional Strengthening	Jean Karam
13:00	***Discussion Forum*** (Rami Zurayk as Facilitator)	
14:00	Lunch	

DAI in collaboration with WESS

Litani Water Quality Management Project (BAMAS)
Litani River Authority Offices, Bechara el Khoury, Beirut, Lebanon
Tel/Fax: +961 1 662 117